A LONGITUDINAL STUDY OF THE LANGUAGE AND MEMORY PROFILES OF CHILDREN WITH HEARING IMPAIRMENT WHO EXHIBIT LANGUAGE LEARNING DIFFICULTIES

SUZI WILLIS

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Abstract

This thesis addresses the vocabulary, language and memory abilities of children with hearing impairment who, despite early provision of hearing aids or a cochlear implant, display substantial difficulties in the development of spoken language: an under-represented group in the literature. The research utilized a longitudinal case series design and standardized vocabulary, language and memory assessments in order to identify patterns and changes in abilities when assessed annually on three occasions. The memory assessment battery contained multiple tests that measure verbal and visual short-term memory and working memory, which enabled an innovative and a comprehensive evaluation of strengths and weaknesses in memory abilities. Six children with hearing impairment who use speech as their primary mode of communication participated in the research. Three data collection points occurred at twelve month intervals within both mainstream schools and schools specializing in the education of children with hearing impairment. This permitted an in-depth assessment of vocabulary and language abilities, as well as the creation of memory and language profiles specific to this group of children. The development of memory profiles from this thesis tentatively suggests that a difference in the quality of auditory input and auditory experience that children with hearing impairment receive may contribute to their difficulties in word storage, early word learning and language development. An exploratory intervention study to enhance vocabulary acquisition was informed by the memory profiles generated in the main study alongside contemporary knowledge gained from other researchers. The aim of the intervention programme was to address the early word learning difficulties and deficits in vocabulary that all the children with hearing impairment in the study exhibited. The findings from the exploratory intervention study provide preliminary evidence for ways in which to individualize therapeutic input for children with hearing impairment who are having considerable difficulties in acquiring vocabulary and developing spoken language.

Acknowledgement

Firstly, I would like to thank the parents and children for participating in this research. I would also like to thank the teachers of the hearing-impaired and speech and language therapists who gave their time and support in organizing assessment visits and meetings to discuss the children.

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Dedication

For My family

Without all of you and Friday Fun Nights,

this thesis would never have been written.

Thank you so much.

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Chapter 1 Introduction

1.1 Introduction to the thesis

This chapter provides an overview of the thesis, which investigates longitudinally the language and memory abilities of six children with hearing impairment and additional language learning difficulties and also examines the implementation of the memory and vocabulary findings from the research study and previous literature within a therapeutic programme with two additional children with hearing impairment.

This study focuses upon the population of children with hearing impairment who have early experience of hearing aid or cochlear implant use, but who have not achieved spoken language equal to that of their peers despite ongoing support from both their parents and professionals. As will be argued in Chapter 2, this cohort is representative of a considerable number of children with hearing impairment.

The thesis adds new knowledge to our understanding of the population of children with hearing impairment who experience additional difficulties in spoken language learning. Firstly, the knowledge gained from this thesis goes some way to offering hypotheses about specific memory difficulties that some children with hearing impairment appear to experience and the long-term language deficits that they encounter. Secondly, it uncovers and provides a greater understanding of their strengths and weaknesses in vocabulary and language development, as well as verbal and visual short-term memory and working memory. Thus, enabling the development of memory and language profiles for this group of children. Thirdly, it explores ways in which to individualize therapeutic input for children with hearing impairment and poor spoken language development.

1.2 The researcher's focus

As a speech and language therapist, I have had the privilege of working with and learning from children with hearing impairment and their families for more than two decades. Many years ago, I began working in the field of cochlear implants as a member of a cochlear implant programme. The children were referred for a cochlear implant because of their minimal useable residual hearing or poor progress with their hearing aids. Whilst working in this clinical environment, I learned that despite early fitting of hearing aids or a cochlear implant, regular intensive therapeutic input, appropriate educational support and close collaboration with families and support teams, a proportion of children with hearing impairment did not acquire spoken language as anticipated. However, there were also other children where the expectation was that their language development would be slower to develop, due to limited access to sound from their hearing aids prior to implantation and the late fitting of their cochlear implant (i.e. after the age of 4;0) and yet these children displayed “linguistic resilience.” That is to say, that even in the context of prolonged auditory deprivation of three to four years and resultant limited spoken communication, a small proportion of children achieved age appropriate language and intelligible speech after four to five years of cochlear implant use. These differences intrigued me. Several years ago, I began receiving referrals from speech and language therapists and teachers of the hearing impairment who provide intervention and support to children with hearing impairment. They were concerned about the children who were making poor progress in their spoken language development. The parents and support teams wanted to know what the problems were, beyond the surface issues of poor language development, and what could be done to remediate them. Finding answers to these questions has been the impetus behind this thesis.

1.3 Rationale for the study

This thesis addresses recurring questions and debates in the field of paediatric hearing impairment. Research in the field of hearing impairment has evolved as technology has advanced at exponential rates. The early research studies focused on speech and language outcomes in children with hearing impairment with different severities of hearing loss. New research questions arose as cochlear implants were introduced during the early 1990s. One of the questions related to “Why some children with a cochlear implant do better than others?” Many researchers have discussed the variables (e.g. age of implantation, communication mode, additional disabilities) that affect progress, but questions remain regarding how different cognitive abilities may affect language development. Researchers have hypothesized that memory abilities related to verbal information may be a causative factor, as weaknesses in verbal short-term memory have been identified in other populations of children with developmental disorders of communication (Alloway et al., 2009a; Alloway et al., 2009b; Archibald and Alloway, 2008; Archibald and Gathercole, 2006a; Botting and Conti-Ramsden, 2001; Briscoe and Rankin, 2009; Freed et al., 2012). However, there is a lack of available literature regarding the outcomes of children with hearing impairment and language learning difficulties (LLD) and memory. The current study addresses some of these issues with particular reference to a cohort of children who display substantially delayed spoken language, even after several years of hearing aid or cochlear implant use. The findings in the research regarding this subgroup of children with hearing impairment are under-represented, but often alluded to, in the literature (See Chapter 2, Sections 2.6, 2.7 and 2.8).

1.4 Background and terminology

Researchers have found that variables such as the age at which a child receives hearing aids/cochlear implant, parental support and communication mode are closely related to spoken language outcomes in children with hearing impairment (Geers et al., 2011; Geers et al., 2009; Geers and Nicholas, 2013; Moeller, 2000; Niparko et al., 2010; Pisoni et al., 2011). The sign language exposure that children with hearing impairment experience is in itself another variable that contributes to the heterogeneity of the population of children with hearing impairment. That is to say, that for a proportion of children with hearing impairment there is inconsistent exposure to sign language or the late acquisition of sign language as a result of failure to acquire speech (Knoors and Hermans, 2010; Knoors and Marschark, 2015; Young et al., 2009; Young and Tattersall, 2007). However, the use of sign language prior to cochlear implantation is not a prohibitive factor in developing spoken language, and in fact has been found to be beneficial for children who go onto receive a cochlear implant by the age of 21 months (Yoshinaga-Itano, 2006). As a way in which to identify the specific factors contributing to their difficulties in spoken language learning, the current study focuses on the cohort of children who use speech as their primary mode of communication. The present research chose to exclude participants who were sign language users, as it is difficult to determine the variability regarding the quality of sign language input and the use of sign language in the home and educational environment. The findings from the current study and other literature demonstrate that a proportion of oral children with hearing impairment do not overcome substantial delays in spoken language learning even though they have had long term access to spoken language input and educational support.

Terminology is at issue in research with language development and with hearing impairment. This thesis examines that population of orally educated children with hearing impairment who exhibit LLD, even after several years of hearing aid or cochlear implant use. It could be thought that children with hearing impairment and LLD are children who have specific language impairment in addition to, but not necessarily as a result of their hearing impairment. The research findings comparing children with specific language impairment and children with hearing impairment and LLD are examined in Chapter 2, Section 2.8. This thesis has chosen to avoid using the term ‘specific language impairment’ or ‘language impairment’ to describe the participants in the thesis for three reasons. Firstly, children with hearing impairment display different patterns of auditory development and speech perception abilities than normally hearing children (See Chapter 2, Section 2.2.). Secondly, children with hearing impairment have a different language learning experience than normally hearing children, in that they require more intensive language input and do not learn spoken language incidentally as their normally hearing peers do. Finally, the terminology regarding specific language impairment is under debate and is a challenge for many in the field of developmental language disorders. Researchers are currently discussing the benefits and limitations of a change in the terminology in relation to ‘specific language impairment’ (See the special issue of International Journal of Language and Communication Disorders, Volume 49, Issue 4, 2014). Academics and clinicians are currently examining the challenges that this label brings and the ramifications of possible changes of terminology both educationally and clinically (Reilly et al., 2014). Therefore, this thesis utilized the term language learning difficulties (LLD), to define a subgroup of children with hearing impairment who experience substantial difficulties in acquiring spoken vocabulary and language, rather than attempting to apply an additional diagnostic category of specific language impairment.

The terminology of “impairment” for the current study was chosen to reflect the The *International Classification of Functioning, Disability and Health Children and Youth Version* (*ICF-CY*) (2007), alongside common usage within the United Kingdom. McLeod and Threats (2008) utilize the ICF-CY when discussing children with communication and hearing disability and its application in assessment and intervention. The term “hearing impairment” is used in this thesis to depict a child who, when wearing their hearing aids or cochlear implant, can hear spoken language at a conversational level (See Chapter 2, Section 2.2).

Finally, regarding terminology, the author is conscious of debates around hearing impairment and a differentiation between ‘hearing impairment’ (as defined above), ‘deaf’, refers to those who see their impairment as disabling and identify more with the hearing world (Valentine & Skelton, 2008). ‘Deaf’ is used to represent a cultural identity and refers to those who identify with the Deaf community and see it as a linguistic and cultural minority. This thesis does not engage with these differences, but does briefly note some of the issues as the literature is reviewed (see Lum, 2010; Valentine & Skelton, 2008).

1.5 Structure of the thesis

The thesis is divided into eight chapters. The following sections outline the content of each chapter and their contribution to the thesis.

1.5.1 Chapter 2 Literature review in the field of paediatric hearing impairment

Chapter 2 begins with an outline of how we hear sound, how it is measured and its relevance to spoken language learning. It also discusses the communication options and educational management of children with hearing impairment, as well as the theoretical background in the field of paediatric hearing impairment in relation to word learning and vocabulary acquisition. The chapter examines previous studies with regard to spoken language development and outcomes in orally educated children with hearing impairment. Chapter 2 ends with an evaluation of the research that has specifically focused on children with hearing impairment who exhibit additional language learning difficulties.

1.5.2 Chapter 3 Memory and children with hearing impairment

Chapter 3 introduces the role memory plays in learning and two recognized theories of memory: the capacity theory (Just and Carpenter, 1992) and the multi-component theory (Baddeley, 2003; Baddeley, 2012). The chapter explains how these models differ in their management of memory and processing abilities. It then examines the predominating model of memory, that of Baddeley (2003), and explores two standardized memory assessments based upon the framework of this model. Chapter 3 considers the literature in the field of hearing impairment and verbal and visual short-term memory and working memory. The chapter also explores ways in which practitioners can address verbal short-term memory or working memory deficits therapeutically. The chapter concludes with an outline of the research questions pertinent to this thesis.

1.5.3 Chapter 4 Methodology

Chapter 4 starts with a brief discussion of the current study and its aims. The chapter continues by considering philosophical and methodological issues and the rationale for the case series design for the present research. The chapter goes on to describe the procedures relating to the recruitment of participants, inclusion criteria and participant characteristics. The processes of data collection and analysis with reference to the specific use of a battery of receptive and expressive vocabulary and language assessments, as well as a battery of memory tests is examined. The chapter closes with a description and rationale for the development of a new memory assessment that was piloted and trialed with normally hearing children and then used with the case series of children in the current study. This test evaluates both verbal and visual working memory utilizing the same words.

1.5.4 Chapter 5 Results

Chapter 5 reports the results from the assessment battery for the six children included in the case series. The structure of this chapter is based upon the research questions being addressed in relation to findings in vocabulary, language, and short-term memory and working memory abilities for the individual children, as well as the group as a whole. The findings from the study pinpoint that the children with hearing impairment and language learning difficulties exhibit better expressive vocabulary than receptive vocabulary; nevertheless, both are significantly delayed in relation to their normally hearing peers and other peers with hearing impairment. These children continue to display considerable delays in expressive language, in particular grammar and syntax. With regard to memory abilities, the children in the case series display a verbal and visual memory profile that is unique in comparison to other children with developmental disorders of language. The children with hearing impairment and LLD demonstrate strengths in visual short-term memory and working memory, but display a weakness in verbal short-term memory tasks which require access to the long term memory such as Word Recall. However, these children with hearing impairment and additional LLD do not exhibit generalized processing deficits.

1.5.5 Chapter 6 Discussion of the case series

Chapter 6 discusses the patterns of vocabulary and language development of the cohort of children with hearing impairment and LLD in relation to the available research. It examines the significance of the memory findings of the research with respect to the existing body of knowledge in the field of paediatric hearing impairment. The chapter discusses the clinical implications of the study regarding vocabulary, language and memory. It examines the development of memory profiles for this population of children with hearing impairment and LLD. It also considers their profile in comparison with other children with developmental disorders of language. The limitations of the research and its applications to clinical practice are considered. Chapter 6 concludes with a discussion of the rationale for an exploratory intervention study based upon the present study's research findings and associated literature.

1.5.6 Chapter 7 Exploratory intervention

Chapter 7 outlines the aims of an exploratory intervention study and the development of the programme, which originated from the findings from this thesis. It examines the implementation of a programme of intervention, and discusses the impact of the intervention on the acquisition of vocabulary and language in two young children with hearing impairment and extremely delayed spoken language development. The chapter concludes with a discussion of the application to clinical practice and the limitations of the exploratory study.

1.5.7 Chapter 8 Conclusion

Chapter 8 summarizes the conclusions drawn from the thesis and the overarching strengths and limitations of the research. It considers the methodological issues of the study and directions for further research. The chapter concludes with a summary of the practical applications and theoretical implications of the research.

Chapter 2 Literature review in the field of paediatric hearing impairment

2.1 Introduction

Chapter 2 begins with a description of how we hear sound and the classification of hearing loss. The chapter continues with a discussion of the effects of auditory deprivation and ways in which hearing loss in young children can be managed by technological means. The chapter also discusses the communication modalities and educational options available to children with hearing impairment and their families. Chapter 2 continues with an evaluation of the vocabulary and language assessments most commonly utilized with children with hearing impairment. The third part of the chapter examines vocabulary development and word learning in children with hearing impairment who use speech or speech and sign language as their primary modes of communication. The fourth section in this chapter explores the literature in relation to the language outcomes in orally educated children with hearing impairment. The final part of the chapter discusses the research that has focused upon children with hearing impairment who exhibit additional difficulties in developing spoken language.

2.2 How we hear, and hearing loss in children

The ear is a transducer, in that it changes the acoustic energy into mechanical energy and finally into electrical energy for the brain to interpret (Cole and Flexer, 2011). The process of hearing begins when sound waves move molecules that are in the air. The sound waves enter the outer ear and travel to the tympanic membrane (i.e. ear drum), where acoustic energy is changed into mechanical energy within the middle ear, where the ossicles are located. This sound wave then vibrates the ossicles in the middle ear. The last ossicle, the stapes, transmits this vibration to the oval window, which is the entrance to the cochlea, part of the inner ear. These vibrations stimulate fluid within the inner ear (i.e. cochlear fluid) and hair cells in the cochlea. The movement of the hair cells within the liquid changes the energy into electrical energy, and these impulses stimulate the auditory nerve, also known as the 8th cranial nerve. The anatomy of the ear and the location of the inner ear, which consists of the cochlea and vestibular system, are presented in Figure 2.1. The cochlea has a tonotopic layout; in that the higher speech frequencies (e.g. 8,000 Hz) are located closer to the opening of the cochlea and the lower frequencies (e.g. 250 and 500 Hz) are located further into the cochlea approximately at the first bend of the cochlea. A useful analogy would be to compare the cochlea to a piano keyboard. That is to say that low frequency sounds (e.g. 250 Hz and 500 Hz) are at one end of the piano, mid-frequency sounds (e.g. 750 Hz and 1000 Hz) are in the middle and high frequency sounds (e.g. 2000 Hz and 4000 Hz) are at the other end of the piano.

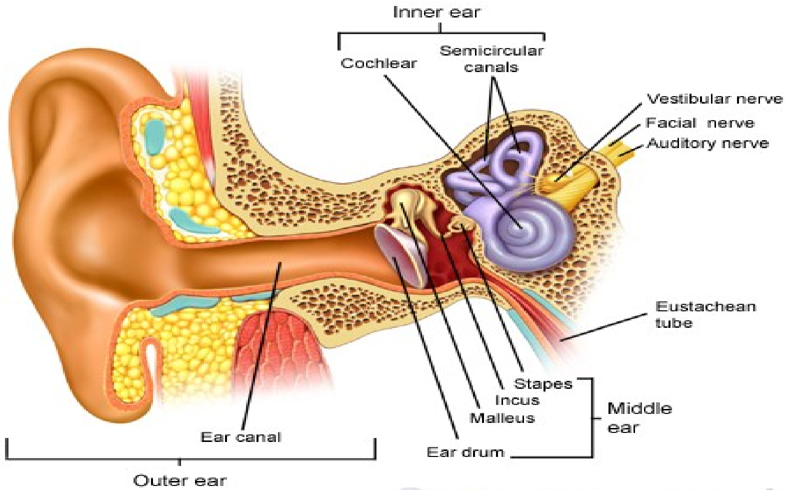

Figure 2.1 **The anatomy of the ear (VCM, 2014)**

This transmission of neural information then continues to the auditory cortex, which is directly involved in interpreting auditory information as meaningful, and in language processing (Kretzmer et al., 2004). The auditory cortex also has a tonotopic layout (See Figure 2.2). If there is damage to the inner ear, this results in permanent, sensorineural hearing loss. This damage may have taken place before or during birth, or as a result of an infection such as meningitis (Cole and Flexer, 2008). Infants in most developed countries can be diagnosed with a hearing loss soon after birth through neonatal hearing screening, which takes place in the hospital after a child is born, or within the first six to eight weeks after birth at a health centre.

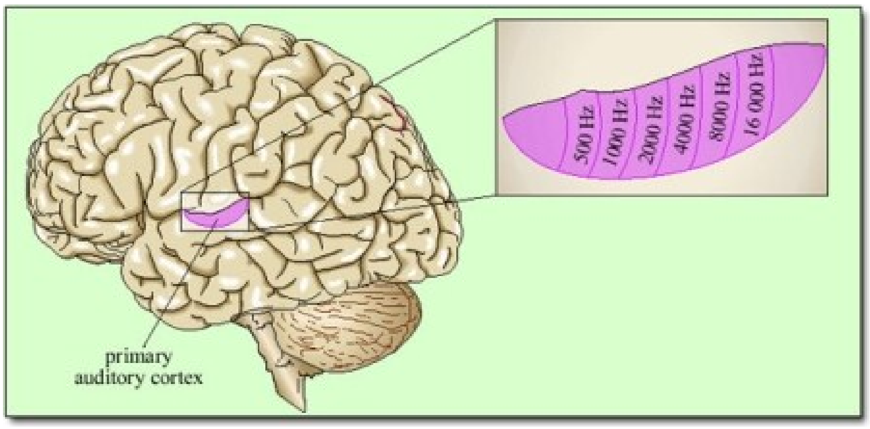

Figure 2.2 **The tonotopic layout of the auditory cortex (SLTINFO, 2015)**

A child's hearing sensitivity is measured by an audiological scientist in the England and recorded on an audiogram. When measuring a child's hearing, the level at which the child can just detect the sound is termed the "threshold." Audiological scientists record hearing levels in decibels (i.e. dB), which describes the intensity of sound that is required for a child to perceive a sound. The levels are recorded on an audiogram (see Figure 2.3) in relation to frequency, also known as pitch, which is measured in Hertz (Hz). In order to develop spoken language, children with a hearing impairment must have access to the speech sounds across the speech frequencies from 250 Hz to 4000 Hz (within the "banana shape" in Figure 2.3) when wearing their hearing aids or cochlear implant which also must be working to specification. Hearing loss is categorized according to degree of hearing loss, ranging from no loss to a mild (20 to 40 dB HL), moderate (41-70 dB HL) severe (71-90 dB HL) or profound (91 dB HL or greater). The classification of hearing loss that clinicians use when describing hearing impairment is illustrated in Figure 2.3.

Figure 2.3 **An audiogram and classification of hearing loss (HearLikeMe.com, 2014)**

2.2.1 Critical periods and the effect of auditory deprivation

The early fitting of hearing aids or cochlear implants does not ensure that children with hearing impairment will attain spoken language levels similar to that of their normally hearing peers (Yoshinago-Itano, 2003). The auditory signal provided by hearing aids and cochlear implants is extremely impoverished compared to that of the normal cochlea. The use of a cochlear implant, which has 22 electrodes and artificially stimulates the auditory nerve, is rudimentary in comparison to the 30,000 hair cells that are finely tuned to stimulate the spiral ganglion. The frequency specific information and dynamic range provided by hearing aids or cochlear implants is also limited in comparison to that of a normally functioning auditory system.

The brain's ability to reorganize itself in the absence of auditory input is well documented in the literature (Musiek and Daniels, 2010; Sharma et al., 2009; Shepherd and Hardie, 2002). The reorganization of brain function, which encourages the use of other senses, predominantly vision, is termed cross-modal reorganization. This process has a strong influence on the development of auditory neural pathways, as well as having an important relationship with critical periods for the development of the auditory centres in the brain and language development (Fallon et al., 2008; Kral and Eggermont, 2007; Kral and

O'Donoghue, 2010; Sharma et al., 2005). The brain is reliant upon repeated auditory experience in order to develop stronger neural connections. This intensive auditory experience is necessary in order to develop the centres in the brain that are in need of auditory development and reorganization in order for children with hearing impairment to have the potential to learn spoken language (Merzenich, 2010; Moucha and Kilgard, 2006). Researchers have found that the earlier in children with hearing impairment's development that they have access to sound through hearing aids or cochlear implants, the greater likelihood that they will develop age appropriate language and intelligible speech (Fallon et al., 2008; Kral and Eggermont, 2007; Kral and O'Donoghue, 2010; Sharma et al., 2005).

2.2.2 Hearing aids and cochlear implants

When a child is diagnosed with a hearing loss, they are typically fitted with hearing aids, which will amplify the incoming sound in order to stimulate any residual hearing. Historically, children were fitted with analogue hearing aids, which would amplify the incoming sound from the environment, potentially enabling the child to detect sound. The fitting of analogue hearing aids did not provide frequency specific amplification. That is to say, individual frequencies could not be amplified selectively. With the advent of digital hearing aids, specific frequencies are amplified in order to allow any residual hearing in the cochlea to be stimulated, thus customizing the hearing aids for that child's type of hearing loss. When customised and worn, digital hearing aids can enable detection of environmental and speech sounds for many hearing-impaired children. The duration of auditory input and exposure to spoken language learning that a child receives via hearing aids or cochlear implants, is termed "hearing age" (Ling, 1989). For example, if a child receives a cochlear implant or hearing aids at the age of 2;0 and uses her equipment for one year, her chronological age would be 3;0 years, but her hearing age would be 1;0 year. Through consistent hearing aid or cochlear implant use, children with hearing impairment can begin to make sense of the sound that they hear and begin to learn spoken language (Cole and Flexer, 2008). Some children, however, do not derive benefit from using digital hearing aids, as speech is still not made accessible to them (See Figure 2.3). These children with a severe or profound hearing loss may benefit from a cochlear implant and possibly then learn spoken language, if fitted with an implant during their pre-school years (See Sections 2.6 and 2.7).

A cochlear implant bypasses the natural way of hearing, described above, and artificially stimulates the hearing nerve. The position and location of the internal and external parts of the cochlear implant device are exhibited in Figure 2.4. The cochlear implant consists of an internal component called a stimulator receiver package (See *2* in Figure 2.4) and external components worn on the pinna, part of the outer ear (See *1* in Figure 2.4). The child must wear external equipment that consists of a microphone, a transmitter coil and a speech processor. The microphone receives sound from the environment and that sound is transformed into electrical signals by the speech processor. Those electrical signals are then transmitted through the transmitter coil. This is held onto the side of the head and connected to the stimulator receiver package via a magnet underneath the skin. The signal is then transmitted through the skin to the cochlea where the electrode array (See *3* in Figure 2.4) artificially stimulates the hearing nerve (See *4* in Figure 2.4). The electrode array from the cochlear implant destroys the residual hearing in the cochlea in the implanted ear. The role of the speech and language therapist and the teacher of the hearing-impaired is to help the child with hearing impairment to make sense of what he/she hears, either using hearing aids or cochlear implants, and support the parents in learning how to make language accessible to them.

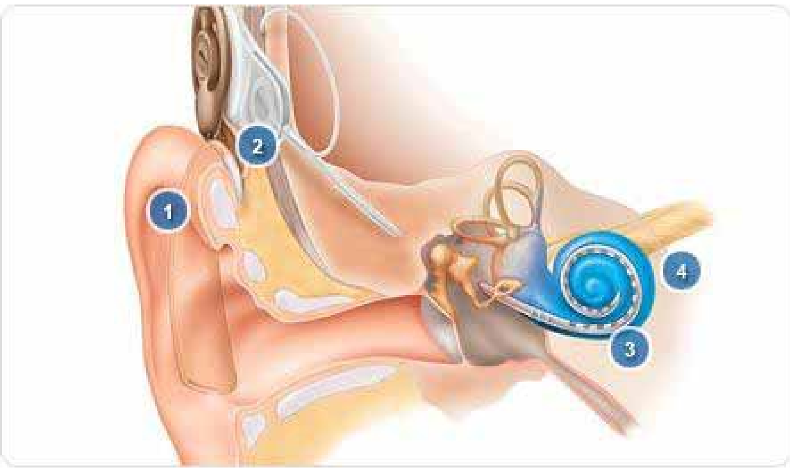

Figure 2.4 **A cochlear implant in situ inside the cochlea with external equipment (Cochlear, 2014)**

2.3 Communication options and educational provision for children with hearing impairment and their families

There are approximately three children per 1000 live births each year who are diagnosed with congenital hearing loss (Bamford et al., 2007; Davis et al., 2011). The aim of UK's Universal Newborn Hearing Screening Programme, is that children with hearing impairment will be diagnosed and fitted with their hearing aids no later than 6 months of age (Moeller et al., 2013). The vast majority (i.e. approximately 95%) of children with hearing impairment are born to normally hearing parents (Mitchell and Karchmer, 2004). Parents of children who are born with a hearing impairment in addition to the small number who acquire a hearing loss prior to developing spoken language (prelingually deafened) are in need of information and support when making decisions about their child's communication development and expectations (Carr, 2009; Young, 2010; Young et al., 2006). Currently, in the England parents of children with hearing impairment are given information and guidance regarding communication options according to the ethos of the region where they live, or the personal beliefs of the professionals who are supporting the, which means considerable variation across the country (Lynas, 2005; Moeller et al., 2013; Young, 2002; Young et al., 2006).

There are many children with hearing impairment, who are able to detect all or some spoken language when wearing their hearing aids. In these situations, parents may choose for their child to use spoken language as their primary mode of communication both at school and in the home environment. This communication mode for children with hearing impairment in the England is termed "auditory-oral" or "oral" (Lynas, 2005). Professionals hope that early identification and fitting will enable children with hearing impairment to acquire spoken language at a rate equal to that of their normally hearing peers. That is to say, that after 1 year of hearing aid or cochlear implant use, the child with a hearing impairment will have exhibited one year's growth in language (i.e. a 1 year language age) and after 2 years of hearing aid/cochlear implant use, 2 years of language will have developed and so on. This is a benchmark for professionals and their families when evaluating progress in spoken language development (Cole and Flexer, 2011). The use of speech alone is a controversial issue and there are two contrasting and strongly held views. Firstly, it is felt by some professionals within the field of hearing impairment and a considerable number of members of the Deaf community, that sign language is the natural language of the Deaf and that to restrict its use with children with hearing impairment is inappropriate. In contrast, a proportion of professionals working with children with hearing impairment believe that the introduction of sign language will reduce the amount of spoken language learning that a child with hearing loss develops and therefore recommends that sign language should not be introduced to the child. Such advice not to use sign language can have a negative impact upon the child's development of broader communication skills and may influence parents to make a decision that sign language is not appropriate, especially if they are wanting their child to develop spoken language (Knoors and Marschark, 2012; Marschark and Spencer, 2010).

Parents may also choose for their child to use both speech and sign language when communicating and to be educated in this manner. This communicative option is termed simultaneous communication or sign supported English (SSE). This can be understood as the simultaneous use of speech with sign language presented in word order of English, or other languages if appropriate (Marschark et al., 2005). In England, professionals often refer to this way of communicating with children with hearing impairment as total communication (T/C) (Lynas, 2005). There is a small proportion of children, who may only hear a limited part of the speech signal even with the most powerful digital hearing aids. These children have a severe to profound or profound hearing loss. In these instances, parents of these children may choose to use sign language as a way in which to communicate with their child, as hearing aids provide limited benefit and access to sound. Some professionals working in the field of hearing impairment and many members of the Deaf community advocate "sign-bilingualism." This approach deems that the child with the hearing impairment be exposed to sign language (in this case British Sign Language) as soon as possible after diagnosis. There are, however, obvious difficulties in teaching sign language to children with hearing impairment. This process relies not only on the parent learning sign language, but also on the sign language competence of support professionals. With reference to school age children with hearing impairment, additional issues become apparent as teachers need to be proficient sign language users, as well as familiar with the subject specific vocabulary and the curriculum (Knoors and Hermans, 2010; Knoors and Marschark, 2015; Leigh, 2008).

It is not uncommon for children with hearing impairment to change from oral to total communication or sign language, because of "failing" to acquire spoken language. Thus, many children come late to learning sign language and have already fallen considerably behind their normally hearing peers in language acquisition (Knoors and Marschark, 2015). When sign language is a child's primary mode of communication, the issue of "how and from whom" parents learn sign language has been a barrier for many parents. The acquisition of language, either signed or spoken, can be highly reliant upon the quality of input from adults and carers (Lynas, 2005; Moeller, 2000; Young et al., 2009; Young and Tattersall, 2007). Some parents may also consider the appropriateness of a cochlear implant, as it may provide greater access to sound. This can be a contentious issue, as some people within the Deaf community do not agree that a cochlear implant is appropriate for children who are born deaf (Cole and Flexer, 2011; Niparko, 2009). This debate is beyond the scope of this thesis, but detail can be seen in Lane and Bahan (1998) and Balkany et al. (1996).

Educational environments

The educational environment for children with hearing impairment in England is related to policy and provision available within the locality where the child lives. Some educational authorities within England have a specialist resource base for children with hearing impairment located within a primary or secondary school. This setting may be suitable for children who use sign language and/or spoken language to communicate. There are also specialist schools for children who are Deaf or have a hearing impairment, located regionally. A small proportion of these schools are privately maintained, while the majority are within the statutory education sector. Alternatively, educational provision for some orally educated children is based within their local mainstream primary or secondary school, with support from a qualified teacher of the hearing-impaired. An additional variable in the decision making for some parents is that their child may need to travel in order to access the specialist support and teaching that is required and/or an educational environment where sign language is used. However, even if the educators know sign language, it does not necessarily mean that they are able to provide the necessary level for educational interpreting (Schick et al., 1999).

2.4 Research trajectory in the field of paediatric hearing impairment

The early research in the field of paediatric cochlear implantation focused on evaluating the effectiveness of cochlear implants in children with hearing impairment by using speech perception testing alongside assessment of receptive vocabulary abilities at six month intervals during the child’s first two to three years of cochlear implant use (Fryauf-Bertschy et al., 1992; Miyamoto et al., 1997; Osberger et al., 1991; Tyler et al., 1997; Waltzman et al., 1994). This research did not differentiate between children with hearing impairment who utilised different communication modes (speech, sign language or total communication). The use of speech perception testing originated from adult cochlear implant research, which followed this assessment protocol. Currently, paediatric and adolescent cochlear implant and hearing aid users continue to have speech perception testing, as a way in which to evaluate their access to speech in different listening conditions (i.e. comprehension of speech alone, speech and lip-read information, and speech presented in noise).

The research into speech and language development in children with hearing impairment has followed a course, whereby researchers initially compared the speech and language outcomes for groups of children with different severities of hearing loss (i.e. mild, moderate, severe, profound) (Moeller et al., 2007; Tomblin and Hebbeler, 2007; Yoshinaga-Itano, 2006). With the advent of cochlear implants, researchers primarily focused on determining whether a cochlear implant provided enough support for spoken language learning (Fryauf-Bertschy et al., 1992; Waltzman et al., 1994). As cochlear implants became more commonly fitted in children with hearing impairment, researchers adopted an alternative route which compared cochlear implant users with hearing aids users, again in the context of different levels of hearing loss (Fitzpatrick et al., 2011; Yoshinaga-Itano et al., 2010). Researchers have also examined the language development of infants and toddlers with hearing impairment and considering hearing aid users with a severe hearing loss and children who use cochlear implant as a single research group, as their aided levels are judged to be at similar levels (i.e. between 20-35 dB HL) (Moeller et al., 2007a; Moeller et al., 2007b).

The following studies demonstrate the state of the research when the present study was designed. Geers et al. (2009) conducted a retrospective multi-centre study of 153 orally educated children with hearing impairment, using normative data from a variety of standardised assessments (See Table 2.1). Their participants were tested between the ages of 5;0 and 6:11years. Their ground breaking research findings demonstrated that receptive and expressive vocabulary, linguistics concepts, grammar and syntax develop at different rates and that certain areas of language (i.e. receptive vocabulary, grammar and morphosyntactic abilities) may benefit more from earlier fitting of a cochlear implant. Other researchers have examined the acquisition of spoken language in children with hearing impairment using hearing aids or cochlear implants and have found that regardless of mode of aided hearing, children with hearing impairment exhibit the same pattern of development as normally hearing children in early word learning and syntactic development, but develop at a considerably slower rate (Cleary, 2008; Lederberg and Spencer, 2009; Moeller et al., 2007b; Moeller et al., 2007). In contrast, researchers have discovered that children with hearing impairment follow a different pattern of development with regard to the development of grammatical morphemes (McGuckian and Henry, 2007; Svirsky et al., 2002). This may be in part due to the perceptual difficulties that children with hearing impairment experience as a result of their hearing impairment. For example, their ability to perceive high frequency sounds such as “s,” which marks plurals and possessives, is more limited in conversational speech than their normally hearing peers. For the purpose of this thesis, the literature pertaining to novel word learning and vocabulary development in orally educated children are the primary areas of focus due to the possibility of targeting these domains in the early stages of young children’s spoken language learning.

2.4.1 Language and vocabulary assessments used with children with hearing impairment

The findings in the spoken language and vocabulary development of orally educated children with hearing impairment have led researchers to re-evaluate the assessment process and delve into different research questions. The current, reoccurring research questions in the field of cochlear implantation and hearing impairment are threefold:

- Why, despite appropriate amplification, is there large variability in spoken language outcomes in children with hearing impairment?

- Are children with hearing impairment able to maintain their rate of vocabulary and language learning and not fall further behind their normally hearing peers by the time they reach secondary school ?

- Is there an added benefit from fitting cochlear implants under the age of 12 months or 2 years?

Researchers are making use of different vocabulary and language assessments standardized on normally hearing children as a way in which to explore further these questions. In order to address the question of large variability in spoken language outcomes in children with hearing impairment, researchers have employed of a range of language assessments (e.g. Duchesne et al., 2009; Geers et al., 2009; Harris et al., 2011; Harris et al., 2013; Hawker et al., 2008; Nicholas and Geers, 2006). Language assessments such as the Reynell Developmental Language Scales (Edwards et al., 1997) have been used to investigate language development in comparison to normally hearing children. This assessment has been utilized to investigate the rate and trajectory of language development in young cochlear implant users (Boons et al., 2012; Duchesne et al., 2009; Manrique et al., 2004; Niparko et al., 2010; Svirsky et al., 2000) (See Table 2.1). Nicholas and Geers (2008) created benchmarking of expected test scores for children with hearing impairment fitted with their cochlear implant between 12 and 38 months, using regression analysis from the Pre-school Language Scales-3 (Zimmerman et al., 1992), the MacArthur-Bates Communicative Development Inventories (Fenson et al., 2007) and the Peabody Picture Vocabulary Test 3 (Dunn and Dunn, 2007). There are now more recent successive versions of the Reynell Developmental Language Scales and the Pre-school Language Scales.

This has allowed researchers to compare their findings from their population of children with hearing impairment with those of other researchers.

The MacArthur-Bates Communicative Development Inventories (Fenson et al., 2007) evaluates very early receptive and expressive vocabulary and grammatical development in young children. It is a parent report instrument that is standardized on normally hearing children between the ages of 8 months and 30 months. As many receptive and expressive vocabulary assessments begin with language levels equivalent to 2;0 or 2;6 years, the MacArthur-Bates Communicative Development Inventories (CDI) provides useful information regarding the earlier stages of vocabulary development and use of gestures. This assessment is organized into semantic categories, which allows for the monitoring of the acquisition of different word types (e.g. nouns, verbs, adjectives, prepositions). Researchers have frequently utilized this test in the early stages of vocabulary development in children with hearing impairment, as it is particularly sensitive to small changes in word learning (Chilosi et al., 2013; Moeller et al., 2007; Nicholas & Geers, 2006; Nicholas & Geers, 2013; Thal et al., 2007). Nicholas and Geers (2008) and Mayne et al. (1999a and 1999b) developed benchmarks for expected vocabulary growth in children with hearing impairment using the Mac-Arthur CDI (Fenson et al., 1993) and MacArthur-Bates CDI (Fenson et al., 2007), which is a successive version of the assessment. The Pre-school Language Scales-3 (Zimmerman et al., 1992) and Reynell Developmental Language Scales 3 (Edwards and Reynell, 1997) are assessments that are also sensitive to monitoring early language acquisition. The use of assessments such as those outlined above has enabled researchers to compare the results of children with hearing impairment and normally hearing children who are chronological age peers and hearing age peers.

The Peabody Picture Vocabulary Test - 3 (Dunn and Dunn, 2007) and British Picture Vocabulary Scales 2 (Dunn et al., 1997) belong to the same family of receptive vocabulary tests. These assessments are frequently employed by researchers and clinicians, in conjunction with expressive vocabulary tests such as the Expressive One Word Picture Vocabulary Test (Gardner, 1979) or the Expressive Vocabulary Test-2 (Williams, 2007). These receptive and expressive vocabulary tests are now combined with other receptive and expressive language assessments to form an assessment battery that comprehensively evaluates spoken language development in children with hearing impairment (Geers et al., 2009; Geers and Nicholas, 2013; Geers and Sedey, 2011; Harris et al., 2013).

Many researchers have made use of the Clinical Evaluation of Language Fundamentals (CELF) tests (Semel et al., 1995 and Semel et al., 2006) in their evaluation of receptive and expressive language development in children with hearing impairment (See Table 2.1). The CELF assessments have subtests that systematically evaluate both comprehension and expressive language abilities. This family of tests has the added benefit of a wide age-range on which it was standardized (5;0-16;11). This has allowed researchers to re-assess the language abilities of the same population of children with hearing impairment, when they are older, using the same test battery (Geers et al., 2009; Geers and Sedey, 2011; Nicholas and Geers, 2013).

In summary, researchers in the U.K and U.S.A. have utilized a core set of standardized assessments in order to evaluate the development of spoken language in children with hearing impairment. These assessments have enabled researchers to investigate the early development of receptive and expressive vocabulary and spoken language in young children with hearing impairment, and the ways in which discrete components of receptive and expressive language develop at different rates. The use of a multifaceted assessment battery is essential with this population of children, where different parts of language develop at different rates (Geers et al., 2009), and as a result strengths and weaknesses can be identified. Assessments such as the MacArthur-Bates CDI and Preschool Language Scales are vital in the assessment of children who receive their hearing aids or cochlear implants under the age of 2;0 years. These tests have also supported researchers in developing a greater understanding of the benefits of early device fitting, because their findings have demonstrated that the earlier a child is fitted with their device, the greater the likelihood that he/she will achieve age appropriate spoken language (Moeller et al., 2007; Nicholas & Geers, 2008; Nicholas & Geers, 2013). The CELF tests have been instrumental in allowing researchers to explore the long-term outcomes for children with hearing impairment. They have also been useful in allowing for an evaluation of whether children have been able to maintain their spoken language abilities into the late primary years and adolescence.

Table 2.1 ***Vocabulary and language assessments most frequently used with children with hearing impairment***

Assessment	Measure	Age range	Studies using this Test	Comments
Peabody Picture Vocabulary Test - Revised (Dunn & Dunn,1981) **Peabody Picture Vocabulary Test-3 (PPVT-3) (Dunn & Dunn, 2007)**	Receptive vocabulary	2;6- 90+	El-Hakim et al., 2001; Fagan & Pisoni, 2010; Geers et al., 2009; Hansson et al., 2004; Harris et al., 2013; Hayes et al., 2009; Pisoni et al., 2011; Stiles et al., 2012	American vocabulary. This assessment is part of the family of receptive vocabulary assessments PPVT and BPVS. In research it is used in conjunction with EVT-2 or EOWPVT.
British Picture Vocabulary Test 2 (BPVS 2) (Dunn et al., 1997)	Receptive vocabulary	3;0-16;11	Hawker et al., 2008	British vocabulary. In research it is used in conjunction with EVT-2 or EOWPVT.
Expressive One Word Picture Vocabulary Test (EOWPVT) (Gardner, 1979)	Expressive vocabulary	2;6-90+	Geers et al. 2009;Geers & Seedley, 2010; Duchesne et al., 2009; Geers & Nicholas, 2013	American vocabulary. Picture based assessment. Often used in conjunction with PPVT-2
Expressive Vocabulary Test-2 (EVT-2) (Williams, 2007)	Expressive vocabulary	2;6- 90+	Archibald & Gathercole 2006; Geers et al., 2009; Archibald & Alloway, 2008	American vocabulary. Picture based test. It is often used in conjunction with BPVS 2 and PPVT-3 in HI and specific language impairment literature
MacArthur-Bates Communicative	Receptive and expressive	Birth-30 months	Nicholas & Geers, 2006; Mayne et al.	American vocabulary. It is a parental reporting

Development Inventories (MacArthur CDI) (Fenson et al., 1995) **MacArthur-Bates CDI (Fenson et al., 2007)**	vocabulary; use of early grammatical morphemes and MLU		1999a & 1999b ; Moeller et al, 2007; Thal et al, 2007; Chilosi et al. 2013; Nicholas & Geers, 2013	assessment. It has been validated for use with HI children in study by Thal et al., 2007
Preschool Language Scales-3 (PLS-3) (Zimmerman et al., 1992)	Receptive and expressive language	Birth-6;11	Nicholas and Geers 2007 & 2008; Geers et al. 2009	American and UK picture and toy based test. It allows and overview of receptive and expressive language
Reynell Developmental Language Scales (RDLS) (Edwards and Reynell, 1997)	Receptive and expressive language	1;9-6;11	Svirsky et al 2000; Manrique et al., 2004;Duchesne et al. 2009; Niparko 2010; Boons et al. 2012; Thal et al., 2007	Toy and picture based assessment. It is more appropriate for younger children. Important to be mindful that the vocabulary may not be familiar to children from diverse backgrounds
Clinical Evaluation of Language Fundamentals-Preschool (CELF-P) (Wiig et al., 1992) and **CELF-Preschool 2 (Wiig et al., 2004)**	Receptive and expressive language	3;0-6;11	Dawson et al., 2002; Spencer 2004; Geers et al., 2009	American and UK versions. It has subtests that evaluate different aspects of comprehension and expressive language, including basics and linguistic concepts and grammatical structures
Clinical Evaluation of Language Fundamentals-	Receptive and expressive language	5;0-16;11	Harris et al., 2011; Geers et al., 2009	American and UK versions. It has subtests that evaluate different

3 (CELF-3) Semel et al. (1995)				aspects of comprehension and expressive language. Receptive and Expressive composite scores can be derived
Clinical Evaluation of Language Fundamentals-4 (CELF-4) (Semel et al., 2006)	Receptive and expressive language and memory	5;0-16;11	Blamey et al., 2001; Beer et al., 2011; Freed et al., 2012; Geers and Nicholas, 2013; Harris et al., 2013	American and UK versions. It has subtests that evaluate different aspects of comprehension and expressive language Receptive and Expressive composite scores can be derived. Also evaluates forward and backward digit recall.

HI = Hearing impairment

2.5 Novel word learning in children with hearing impairment

The concept of *novel word learning* refers to children learning the meaning of new words in the presence of the relevant referent, with a limited number of exposures. Researchers have found that there is a strong relationship between the size of children's lexicon and the ability to learn novel words (Adams and Gathercole, 2000; Gathercole et al., 1999; Graham et al., 1998). It is proposed that children need a critical mass of vocabulary in order to learn novel words in a less direct way (Golinkoff et al., 1994). Therefore, the fundamental process of novel word learning has a direct relationship to the development of a child's vocabulary. Novel word learning in children with hearing impairment has traditionally been evaluated by exposing children to nonsense words in an introductory phase and evaluating if the child has retained the nonsense word in a second phase. Many researchers in the field of hearing impairment have used similar methods mirroring the procedure utilized by Gilbertson and Kamhi (1995) (for an in-depth description of the specific procedures see Gilbertson and Kamhi, 1995). This seminal study evaluated novel word learning abilities in twenty children with mild to moderate hearing loss and compared them with twenty normally hearing children matched by receptive vocabulary using the Peabody Picture Vocabulary Test – Revised (Dunn and Dunn, 1981). The ages of the children in the study ranged from 7;9 to 10;7 years for the children with hearing impairment and 5:1 to 9;7 years for the normally hearing children. They found that half of the children with hearing impairment (ten) displayed poorer ability to learn new words than the other children with hearing impairment and the normally hearing children in the study. These children required more exposure to target words in order to learn them. Gilberston and Kamhi (1995) concluded that some children with hearing impairment learn novel words and learn language in a similar way to their normally hearing peers but some children with hearing impairment have language impairment in addition to their hearing loss. Information on the age of diagnosis of hearing loss and age of fitting of hearing aids was not included in this study. This is important because there may be a relationship between the age of identification and remediation of the children's hearing impairment and their difficulties in learning novel words. That is to say that, the differences could be attributable to the late diagnosis/fitting of their hearing aids (See Table 2.2).

Lederberg et al. (2000) evaluated the novel mapping abilities of nineteen children with hearing impairment aged between 3;2 and 6;10 years, who were educated through total communication. They were interested in determining if there was a relationship between vocabulary size and the acquisition of novel word learning strategies, which would allow the child to generalize word meanings to new contexts. They found that children with hearing impairments' ability to learn novel words in the word learning tasks was strongly correlated with the size of their lexicon, regardless of the child's chronological age. They concluded that there was a critical mass of vocabulary, of at least 200 words, that must be acquired before children can infer the meaning of novel words from the context of the sentence or a communicative situation.

Lederberg and Spencer (2009) further investigated word learning abilities in a larger study of 98 children with hearing impairment. These children were educated using speech (i.e. oral), speech and sign language (total communication), or sign language approaches only, to communicate their needs. The children were aged between 2;3 and 6;10 years, displaying a mix of hearing losses ranging from mild to profound. The mean age of identification of hearing impairment was 17 months for acquired losses and 18 months for congenital hearing losses. Lederberg and Spencer (2009) investigated the three stage developmental sequence of word learning: slow word learners; rapid word learners who require direct reference; and novel mappers who acquire words more incidentally, but still benefit from the referent being explicitly shown to them. This process is evident in typically developing children (Golinkoff et al., 1992), as well as across a range of developmental disorders such as specific language impairment (Dollaghan, 1987; Weismer and Evans, 2002), Down's syndrome (Mervis and Bertrand, 1995) and William's Syndrome (Stevens and Karmiloff-Smith, 1997). Lederberg and Spencer (2009) found that these three stages of novel word learning appeared to be a universal process for children with hearing impairment, irrespective of language modality. They concluded that not only did young children with hearing impairment learn words more slowly, but that they may also require extra time at early stages of direct word learning. They also found that word learning abilities in young children with hearing impairment were significantly related to lexicon size, but not degree of hearing loss or educational environment.

Stelmachowicz et al. (2004) examined novel word learning abilities in eleven children with mild to moderate hearing loss, aged between 6 and 9 years old. They compared performance of children with hearing impairment with twenty normally hearing chronological age matched peers, finding that that the children with hearing impairment were poorer at learning new words in comparison with the normally hearing children. They found that receptive vocabulary, measured by the Peabody Picture Vocabulary Test-3 (Dunn and Dunn, 2007), and number of repetitions of target words were significant predictors of novel word learning ability. It is important to note that the mean age of identification of the children's hearing loss was 3;9 years, with only three of the eleven children with hearing impairment being diagnosed with a hearing loss under the age of two. The late diagnosis may have been due to their mild to moderate hearing losses, which can be more difficult to diagnose. Their late identification of hearing loss is a limitation that may have negatively affected the children's novel word learning abilities and most definitely their receptive vocabulary scores.

Houston et al. (2005) examined the receptive and expressive naming abilities of twenty-four children with cochlear implants, who used spoken language as their sole means of communication. The children with hearing impairment were placed into two age groups: ages 2 to 3 years and ages 4 to 5 years. Their ability to learn novel words was compared with chronological age matched normally hearing peers. The study made use of names, which depicted attributes of the Beanie Baby toys (e.g. Stripy for an animal that had stripes on it). This procedure differed from previous explorations of novel word learning (e.g. Gilbertson and Kamhi, 1995; Lederberg and Spencer, 2009), as there was a semantic element to the "nonsense" name of the stimulus. They found that the children with hearing impairment exhibited poorer word learning abilities, both receptively and expressively, than their normally hearing peers. It is important to highlight that the mean age of implantation in the younger group was 20.6 months and 37.3 months in the older group. Houston et al. (2005) would have perhaps seen a different pattern of results if normally hearing peers of the same hearing age (Cole and Flexer, 2008) were included in the study. It would also be of interest to know if the children with hearing impairment in this study had reached the critical mass of approximately 200 words that enables the acquisition of new words to be learned with fewer direct exposures to the meaning of the word (Lederberg and Spencer, 2009) as this was not reported.

Houston et al. (2012) compared the word learning abilities of twenty-five children with cochlear implants aged between 22 and 40 months with normally hearing peers aged between 12 and 40 months. The children with hearing impairment consisted of eighteen children who were oral and seven children who used total communication. This study differed from previous studies in that it focused on the population of cochlear implant users who had received their implant prior to their second birthday. They found that their ability to learn novel words was correlated with the early fitting of their cochlear implant device. The children who received their cochlear implant by the age of fourteen months or had pre-implant hearing performed better in the word learning task, in comparison to the older children with hearing impairment who were unable to learn the novel words. The authors also took account of hearing age of the infants (10.3 to 20.1 months) but found this not to be a factor in learning novel words. Houston et al. (2012) commented that these results may be influenced by the age of the children in the older group of cochlear implant users, as they may have been indifferent to/uninterested in the word learning task and stimuli due to their chronological age. It can be conjectured that the word learning task was more appropriate for the younger children with a cochlear implant. Houston et al. (2012) also addressed the issue of hearing age by comparing the cochlear implant users with hearing age controls. However, they found that hearing age was not a contributory factor when evaluating variability of functioning on this task. Again, the difference in chronological age of the normally hearing children and children with hearing impairment may have had an influence on their ability to attend to, and be interested in, the word learning task.

2.5.1 Summary of novel word learning in children with hearing impairment

In summary, some children with hearing impairment struggle to learn novel words. The late fitting of their hearing aids or cochlear implants may influence this difficulty. Researchers have found that the limited vocabulary of children with hearing impairment has a negative impact upon their ability to learn novel words. It has also been suggested that there is a universal process, by which children with hearing impairment learn new vocabulary items, which is irrespective of their communication mode (i.e. oral, total communication or sign language). From this literature, it is hypothesized by the current author that children with hearing impairment may need to spend more time in the direct, intensive word learning stage than normally hearing children. This will enable the children with hearing impairment to develop a critical mass of vocabulary that will allow them to learn new words with less direct, concentrated adult input.

Table 2.2 ***Research into world learning in children with hearing impairment***

Word Learning Research	Sample Characteristics	Hearing Loss or Cochlear Implant	Measure	Comments
Gilberston and Kamhi (1995)	HI n=20 Ages: 7;9-10;0 NH n=20 Ages: 5:1-9;7	Mild to moderate	Novel word learning	Researchers stated that half of the children with HI had language impairment n=10.
Lederberg et al. (2000)	HI n = 19 Ages: 3;2-6;10 years	Moderate to Severe = 4 Severe n = 8 Profound n =7	Word learning skills, including novel words	Despite language mode, all children exhibited the same process of word learning, which is related to vocabulary size.
Stelmachowicz (2004)	HI n= 11 Ages: 6-9 years NH n =20	Mild to moderate	Novel word learning	They found that receptive vocabulary and number of repetitions of target words were significant predictors of ability.

Hansson et al. (2004)	HI n= 18 Ages: 9;1-13;3 SLI n= 27 Ages: 8;6-11;4 NH= n = 38 Ages: 9;5-12;4	Mild to moderate	Novel Word learning, working memory	A Swedish study. All children were educated orally. The mean age of identification = 4;3 Used Gilberston and Kamhi task. HI within normal range of hearing peers, all NH and HI children in study had difficulty with novel word learning task. Children with HI performed better than SLI children in all tasks.
Willstedt-Svenson et al. (2004)	HI n = 15 Ages: 5;4-11;5	Cochlear Implant	Novel word learning, working memory	A Swedish study. The mean age of fitting of CI was 3;4. One child was fitted under the age of two. Age of cochlear implant was greatest predictor of novel word learning ability
Pittman et al. (2005)	HI n= 37 NH n = 60 Ages: 5-14 years	Moderate	Rapid word learning	Ability to learn words is poorer in children with HI than NH peers, regardless of their age. This correlates with their lower receptive vocabulary scores. Age of diagnosis and fitting of hearing aids of children is unknown
Houston et al. (2005)	HI n= two groups of 12	Cochlear Implant	Word learning	Used object names that related to attributes of Beanie Baby toys. Used chronological age matched peers not hearing age peers

	NH= two groups of 12 Ages: 2-3 years Ages 4-5 years			
Lederberg and Spencer (2009)	HI n = 98 Ages: 27-82 months	Mild = 3 Moderate = 14 Moderately-Severe = 9 Severe = 20 Profound = 46	Word learning skills, including novel words	Word learning abilities were significantly correlated with lexicon size in all educational environments(i.e. speech, TC or sign language). Developmental stages were identified in all communication modalities
Houston et al. (2012)	HI n= 25 Ages: 22-40 months NH 25 age matched controls also:	Cochlear Implant	Word learning	Study took place 12-18 months after CI in children fitted. Children fitted with CI prior to age of two. Young CI users performed better than older CI users. Perhaps a confounding variable was the possible lack of interest in the task for older children. Hearing age (10.3-20.1 months) was not an important factor in learning novel words

	NH infants aged: 12 months n = 23 15 months n= 23 18 months n = 25 21 months n = 28			

HI = hearing impairment HL = hearing loss CI = cochlear implant HA = hearing aids

NH = normally hearing

2.6 Vocabulary development in orally educated children with hearing impairment

2.6.1 The history of research designs in vocabulary development in children with hearing impairment

The early research findings in the field of vocabulary development in children with hearing impairment who are hearing aid or cochlear implant users did not differentiate, within their results, children who were oral from those who used total communication (El-Hakim et al., 2001; Kiese-Himmel, 2008; Kiese-Himmel and Reeh, 2006; Moeller, 2000; Young and Killen, 2002). This initial research also compared the vocabulary skills of different age groups of children with hearing impairment. It also emphasized that the earlier the child is fitted with their equipment, the better their vocabulary development (Connor et al., 2006, El-Hakim et al., 2001, Kiese-Himmel, 2008, Kiese-Himmel and Reeh, 2006, Young and Killen, 2002). The more recent studies in the last decade have compared the vocabulary development in orally educated children with hearing impairment with their normally hearing peers, as well as evaluating the added benefits of earlier implantation (See Table 2.3).

2.6.2 Orally educated children with hearing impairment and their vocabulary development

The current research in the field of hearing impairment and cochlear implant has focused on the population of children with hearing impairment who used speech as their primary mode of communication and were also fitted with their hearing aids or cochlear implant by the age of 2;6 (Duchesne et al., 2009; Fagan and Pisoni, 2010; Hayes et al., 2009; Nicholas and Geers, 2008; Nicholas and Geers, 2013; Stiles et al., 2012). Moeller et al. (2007b) conducted a prospective, longitudinal study over a period of fourteen months with twelve oral infants (from 10 to 24 months of age) using the MacArthur-Bates Communicative Development Inventories (Fenson et al., 2007). All the children with hearing impairment were identified with hearing loss by 12 months of age, with the mean age of diagnosis being 2;6 months. The researchers compared the vocabulary and vocalization abilities of these infants with hearing impairment with normally hearing peers. The children with hearing impairment had similar receptive vocabulary development at

10 to 16 months of age, but their transition to utilizing words expressively was slower than that of their hearing peers. It is interesting to note that four of the twelve children with hearing impairment and two of the twenty-one normally hearing children exhibited vocabulary development that did not follow a typical pattern. Unfortunately, it is unclear from Moeller et al.'s paper whether it is a consistent type of pattern or if each child is following a different pattern.

Hayes et al. (2009), in their longitudinal, three year study of receptive vocabulary development in sixty-five children with hearing impairment, found that children who received their cochlear implant when they were younger had greater rates of vocabulary development than those fitted with their cochlear implant later. That is to say, that if a child was fitted with their cochlear implant by the age of 2;0 years, they could be expected to achieve receptive vocabulary equal to that of normally hearing peers by the age of 4;0 to 5;0 years. Nicholas and Geers (2008) found similar results in their retrospective evaluation of 76 oral cochlear implant users who were implanted between 12 and 38 months age. Their study, based in the USA, revealed that if children are implanted by 12 and 13 months of age and receive regular speech and language therapy support, they could be expected to achieve age appropriate scores on the Peabody Picture Vocabulary Test and MacArthur-Bates CDI (expressive) by age of four to five years. However, it is unclear how many children in the study were fitted with their cochlear implant by the age of 13 months. In contrast, Duchesne et al. (2009) further investigated receptive and expressive vocabulary and language development in their study of twenty-seven French, orally educated cochlear implant users aged between 3;0 to 8;0 years. The children in this study received their cochlear implant by the age of 28 months. These results stressed that while some children benefit from early fitting of a cochlear implant, it does not ensure that they will attain the highest vocabulary and language scores. Duchesne et al. (2009) also found that four different profiles emerged. The first profile was shown by four children who attained scores within the normal range across all language areas, with some children displaying above average abilities. The second group included three children exhibiting general language delay, while the third group of four children had expressive vocabulary abilities within the typical range at the single word level, but still displayed receptive language delays. The fourth profile, with four children, displayed very poor scores in receptive vocabulary, comprehension of morphemes, and syntactic structures, but scored within normal limits in expressive vocabulary and understanding of concepts. The children in the Duchesne et al. (2009) study all received their cochlear implants between the ages of 8 months and 28 months. At the time of the study their participants were aged between 3;6 and 8;3 years, which is considerably younger than the case series of children in the current study.

Geers and Nicholas (2013) in a multicentre, prospective follow on study from Nicholas and Geers (2006), investigated whether the developmental trajectories in relation to the vocabulary and language abilities in 60 cochlear implant users fitted with their device between 12 and 38 months were maintained. The children with hearing impairment were originally assessed at the age of 4;6 years and then again at 10;6 years. They found that the children with higher standard scores at age 4;6, continued with greater standard scores at age 10;6. Geers and Nicholas (2013) also found that the standard score for some children at age 4;6 had improved by the age of 10;6. That is to say that, eleven of the children who had scores 1 standard deviation below the mean at age 4;6 (i.e. below normal limits) achieved scores within normal limits at age 10;6. The mean standard score at age 4;6 was 84, while at age 10;6 the mean standard score was 95. In summary, Geers and Nicholas (2013) found that by the age of 10;6, 72% of their participants had developed receptive vocabularies within one standard deviation of the normative mean, while 82% of the children also attained age appropriate scores on expressive vocabulary. These findings can be viewed in a wider context in that this population of orally educated children with hearing impairment were from higher socio-economic backgrounds and continued to receive intensive therapeutic input throughout the study period. This variable may well have had an impact upon the positive research findings.

2.6.3 Is earlier really more advantageous?

One of the current debates in the field of cochlear implants has focused on whether children fitted with their cochlear implant equipment under the age of 12 months and those fitted between 12 and 24 months acquire vocabulary and language at a similar rate or do the children fitted before twelve months develop faster than later fitted children. Caselli et al. (2012) investigated the vocabulary and language abilities of seventeen young Italian children with hearing impairment aged between the 44 and 65 months of age. These children were fitted with their cochlear implant between the ages of 12 and 22 months. This study is unique in that it matched the young children with cochlear implant with both chronological age matched peers and hearing age matched peers. Caselli et al. (2012) utilized the Lexical-Phonological Test (LPT) (Vicari et al., 2007) for the assessment of lexical comprehension and production abilities. The children with hearing impairment in this study achieved age appropriate expressive vocabulary but not receptive vocabulary. These results are mirrored in research by Chilosi et al. (2013), in their longitudinal study of six Italian children with hearing impairment who received their cochlear implant between the ages of 16 and 24 months. They too discovered that expressive vocabulary developed faster than receptive vocabulary, but both areas remained delayed in relation to normally hearing peers. This developmental lag continued throughout the duration of the three year study. One limitation of the study was that their results were reported in terms of age equivalent abilities, not standard scores. Nicholas and Geers (2013) evaluated the vocabulary and language abilities of 69 children with hearing impairment at age 4;6 using the PPVT-3 and the PLS-4. The children in this American study were fitted with their cochlear implant device between 6 and18 months. The infant group consisted of 27 children (younger infant group) who were fitted with their cochlear implant under the age of 12 months and a group of 42 children with hearing impairment who were fitted with their implant between the ages of 12 and18 months (older infants). The “younger infant group” of children with hearing impairment achieved higher scores on all measures than their later-fitted counterparts. That is to say, that 84% of the younger infant group with hearing impairment reached age appropriate receptive vocabulary scores in comparison to only 69% of the older infants with hearing impairment. It is important to clarify that the population of parents in this study were represented by proactive adults who sought out a cochlear implant for their child under the age of 2;0 years. Also, notably, 80% of the mothers of the children with hearing impairment had a university education in comparison to the 20% of the normative reference group. It is also worthwhile to note that despite receiving a cochlear implant at a young age, approximately 20% of the children with hearing impairment did not achieve receptive vocabulary scores commensurate to that of the normally hearing peers, even after three to four years of device use.

To conclude, researchers have discovered that expressive vocabulary develops more quickly than receptive vocabulary and vocabulary development is influenced by the age at which the child receives their hearing aids or cochlear implant. It is also evident, however, that even in the most optimal situations of intensive family and education support and early access to sound under the age of 18 months, a noticeable proportion of children do not attain vocabulary skills commensurate to that of their normally hearing peers by the age of 4;6. In the long term, many children with hearing impairment may achieve vocabulary skills similar to their hearing peers, but may still have deficits in receptive and expressive language.

Table 2.3 ***Summary of vocabulary research in children with hearing impairment***

Vocabulary Research	Sample characteristics	Hearing Loss or Cochlear Implant(CI)	Comments
Moeller (2000)	HI n = 112 Ages: 5;0-5;11 59 = oral 51 TC	Mild to severe Oral and TC Mild = 9 Mild to mod = 17 Moderate = 19 Severe = 20 Profound = 47	Mean age of identification was 1.55 years. No significant difference in scores due to communication mode. Children with HI identified after age of two were 1-1.5 SD below NH peers at age five. Children enrolled in therapy programme prior to the age of 1 performed equal to that of NH peers at age 5, irrespective of hearing loss
El-Hakim et al. (2001)	HI n= 60 PPVT HI n= 52 EOWPVT Ages: 1;9-11;6 Grouped into under and over five	Cochlear Implant 51 oral 8 TC 1 SL	Retrospective study. The authors used age equivalent scores in their findings. Mean age at CI for PPVT-R was 5;1 years and 5;3 years for EOWPVT

Young and Killen (2002)	HI n = 7	Cochlear Implant with minimum of 5 years CI use 3 Oral 4 TC	Age at implantation ranged from 2;3-6;10 years PPVT-R: no child within normal limits Expressive vocab was a particular area of strength in that 4 out of 7 children had age appropriate scores
Connor et al. (2006)	HI n=100 12-30 months n=21 31-42 months n=15 43-84 months n=20 85-120 months n=44	Cochlear Implant Oral	Investigation of rates of vocabulary development over time found that age at CI was greatest predictor of language and vocabulary ability, with children receiving CI under age 2;6 achieved a similar rate of receptive vocabulary growth to that of NH peers after three to five years of CI use. They did not however “catch up”
Kiese-Himmel and Reeh (2006)	HI n=27 Ages: 2;0-4;4 (time 1) Ages: 3;6-6;0 (time 2)	Mild to profound Mild = 5 Moderate = 11 Severe= 8 Profound= 3	Mean age of participants when fitted with HA = 32.3 months. Severity of hearing loss was related to poorer vocabulary scores. Vocabulary assessed three times over 18 month period. 2/5 children with mild loss and 2/11 with moderate loss had age appropriate vocabulary by time three
Thal et al. (2007)	N= 24 Age= 32-86 months	Cochlear Implant Oral	Mean age of fitting of HA at 11;9 months and CI at 28.60 months. The purpose of this study was to validate the use of the MacArthur CDI and it use in conjunction with other assessments. Authors

	Under 67 months =21 72-86 months = 3		acknowledge that this sample is not representative of the paediatric CI population
Moeller et al. (2007b)	HI n= 12 NH n= 21	3 = Cochlear Implant 9= Hearing Aid	Prospective Longitudinal study. 12 early-identified infants with hearing loss were compared over a period of 14 mo. (from 10 to 24 mo. of age). All children HL identified by twelve months. Most HI children displayed the same pattern of development but delayed
Kiese-Himmel (2008)	HI n=33 23= oral children 10= bilingual/bicultural Ages: 28 and 63 months	Mild =10 Moderate = 17 Severe = 4 Profound = 2	Prospective longitudinal study over 18 months Mean age of HA fitting was 53.3 months Poorer scores were significantly related to age of diagnosis and severity of HL
Nicholas and Geers (2006)	HI n= 76 12-18 months = 26 19-24 months = 20 25-30 months = 11 31-38 months = 19	Cochlear Implant Oral	Retrospective study. Age of implant between 12-38 months. Mean age was 23 months. If implanted by 12-13 months children achieved age appropriate score on receptive and expressive vocabulary by the age of 4;6 years
Duchesne et al. (2009)	HI n= 27 CI by age of 28 months	Oral three children used oral and occasional signing when needed	Study of French children aged 3-8 years who received their CI by the age of 28 months. Early fitting of device does not ensure the best vocabulary and language outcome

Geers et al. (2009)	HI n = 153 CI between Oral Fitted with CI:11 months to 5;1 years	Oral	A retrospective, multi-centre study. Mean age of CI fitting was 2;4 years . Children assessed between the ages of 5 and 6. Expressive vocabulary scores were better than receptive scores.
Hayes et al. (2009)	HI n=65 Ages: 2;8-9;2 years	Cochlear Implant Oral school for HI children. Intensive auditory oral programme	Longitudinal study whereby children assessed annually for three years. All had CI by age of 5 years and mean age of fitting was 2.69 year. All children diagnosed by age of three. Mean chronological age at first test time was 5. If fitted with CI by age of 2;0, children can achieve age appropriate receptive vocabulary within two or three years of implant use.
Fagan and Pisoni (2010)	HI n=23 Ages: 6-14	Oral CI users who received CI aged between 1.4-6 years	Vocabulary scores equal to that of hearing age peers (i.e. duration of CI use) not chronological age (CA) peers. Mean CA in study was 9;1 but hearing age was 6;6. Mean standard score for CA was 78.96, but 100.48 for hearing age. 9 out of 23 had age appropriate score. 18 out of 23 within hearing age
Caselli et al (2012)	HI n=17 NH same age n =17 NH same hearing age = 17	Oral CI users who received	Italian study. mean age of fitting was 16 months and assessment of vocabulary was at 30–44 months (M = 37 months). Children achieved better expressive vocabulary scores than receptive vocabulary
Stiles et al. (2012)	HI n= 18 NH n = 24	Mild to Moderately Severe	Oral HI children had lower standard scores but still within normal limits for their CA. Authors hypothesized that this was as a result of limited auditory exposure to words due to their HI. No information regarding age of HA fitting given. Given the current climate of early

	Ages:6-9 years		diagnosis and fitting and the results, you can hypothesize the children were fitted prior to the age of two.
Geers and Nicholas (2013)	HI n= 60	Oral CI Oral	Multicentre, prospective follow on study from Nicholas & Geers (2006). Vocabulary abilities in high achieving children with CI were sustained. Some children achieved age appropriate scores at age 10;6, when previously their scores at age 4;6 were more than one standard deviation below the mean
Chilosi et al. (2013)	HI n=6	Oral CI	Italian prospective study. CI between ages 16-24 months of age. Assessed on average three times over during the longitudinal study. Expressive vocabulary using, One-Word Picture Vocabulary Test (OWPVT) (Brizzolara, 1989) developed faster than receptive vocabulary.
Nicholas and Geers (2013)	HI n= 69 6 to 11 months: n = 27 12-18 months n = 42	Oral CI	Compared receptive vocabulary results of CI users who were fitted prior to age of 12 months with a group of children fitted with their CI between 12 and 18 months of age. All children were tested at 4;6 years.

*HI = hearing impairment HL = hearing loss CI = cochlear implant HA = hearing aids

NH = normally hearing

2.7 Language outcomes in children with hearing impairment who are learning language through oral means

Following on from studies that focus on receptive and expressive vocabulary, researchers have attributed the variability in spoken language outcomes in children to factors such as age of implant/hearing aids, communication mode, and family support (Duchesne et al., 2009; Geers et al., 2009; Hayes et al., 2009; Moeller, 2000; Nicholas and Geers, 2007; Nicholas and Geers, 2008; Peterson et al., 2010; Sarant et al., 2009; Spencer, 2004). These variables have been found to be most strongly associated with spoken language achievement. Geers et al. (2009) retrospectively investigated the vocabulary and language results from standardized assessments of 153 cochlear implant users aged between the ages of five and six years old. This multi-centre study comprised children with hearing impairment enrolled in one of thirty-nine oral education programmes, across twenty American states. These researchers found that expressive vocabulary developed quicker than receptive vocabulary, and that individual parts of language develop at different rates. They also discovered that certain areas of language, such as receptive vocabulary development, benefit from earlier auditory experience. Their study also found that the performance on language related subtests, such as Recalling Sentences and Word Structure on the Clinical Evaluation of Language Fundamentals (CELF), was poorer in comparison with the vocabulary scores. The children in this study received their cochlear implants between the ages of 11 months and 5;1 years, with the mean age being 2;4 years. Geers et al. (2009) also found that 58% of the children attained scores within 1 standard deviation in expressive vocabulary, whilst only 50% attained this level of functioning in receptive vocabulary. They also performed less well on receptive language, in that only 47% achieved age appropriate language and 39% in expressive language (See Table 2.3). Their research highlighted that the children who were implanted earlier achieved higher scores on all language assessments than the later implanted children in the study. The finding that vocabulary developed faster than other areas of language may be a result of educational input, whereby teachers and therapists target vocabulary more than other aspects of language.

Sarant et al. (2009) evaluated the language levels of forty-two orally educated French children with hearing impairment between the ages of 1;0 and 6;0 years. They found that even though 60% (n = 24) of the children in this study were identified with hearing loss by the age of 12 months, fitted with their equipment and receiving early therapeutic input by the age of one, only 50% (n = 12) of these children developed language equal to that of their hearing peers. It would be of interest to re-assess the language abilities of this group of children with hearing impairment who lagged behind their peers at the age of 10;6. This would have allowed researchers to compare their findings with larger scale studies and thus gain greater insight into the language learning processes of the considerable proportion of children with hearing impairment. It would address the question as to whether these children with delayed language are able to “catch up” or at least not fall further behind in some areas of spoken language development. This is discussed with regard to other research below.

2.7.1 Can children with hearing impairment maintain their rate of spoken language learning?

A second contemporary debate in the field of hearing impairment has focused on whether children with hearing impairment are able to maintain their rate of vocabulary and spoken language learning, as they grow older (Geers and Nicholas, 2013; Geers and Sedey, 2011). Geers and Nicholas (2013) investigated whether the vocabulary and language abilities in 60 cochlear implant users fitted between 12 and 38 months maintained their relative performance at the age of 10;6 (see section 2.6.2 for further discussion of the study). The children with hearing impairment were tested at approximately 4;6 years in the original study (Nicholas and Geers, 2006) and again at 10;6 years. In the earlier study, 27% of the children achieved language scores commensurate to with that of their normally hearing peers on all tests, while in the 2013 study 48% of the children attained scores within normal limits on the CELF-4. Interestingly, 73% of the population of children fitted between 12 and 18 months of age achieved age appropriate scores on the entire test battery by the age of 10;6. The strongest predictor of language abilities at the age of 10;6 was the children’s language scores at 4;6. A summary of the subtest standard scores at age 10;6 are in Table 2.4.

Table 2.4 ***Summary of CELF-4 results for participants aged 10;6 from the study by Geers & Nicholas (2013)***

CELF-4 Subtests	Mean Standard Scores *
Word Classes (Receptive)	8.73
Understanding Paragraphs	8.23
Concepts & Following Directions	7.12
Word Classes (Expressive)	8.95
Formulated Sentences	9.85
Recalling Sentences	7.47

(*Standard scores less than 7 are more than 1 standard deviation below the mean)

The study's findings may not be representative of all children with hearing impairment as the parent population of this study were more highly educated and in a higher income bracket than the normative sample group. In addition, all the children in this study benefitted from early spoken language input from the age of three. In other words, other children with hearing impairment may not fare as well as the children with hearing impairment in this study due to different packages of intervention and parental education and support. It is also of note, that there may be an added benefit of re-evaluating the vocabulary and language abilities of children with hearing impairment over time. That is to say, that older children may have "caught up" with their normally hearing peers by the age of 10;6 or perhaps at least maintained their relative level of functioning. This would suggest that the children were following a typical, albeit delayed, trajectory.

2.7.2 Language outcomes in children with hearing impairment fitted with their device under the under the ages of one and two.

Currently, studies are evaluating the added benefit of a cochlear implant under the age of 12 months in comparison to 18 months, 2;0 years, and 3;0 years of age. Many researchers have found that hearing aid fitting and cochlear implantation under the age of 2;0 years has added benefits in acquiring spoken vocabulary and language at an accelerated rate (Boons et al., 2012; Caselli et al., 2012; Chilosi et al., 2013; Duchesne et al., 2009; Nicholas and Geers, 2013; Yoshinaga-Itano, 2003). In this context, researchers are beginning to assert that there may be an advantage for children receiving cochlear implants under the age of 1;0 year. Nicholas and Geers (2013), in their study of sixty-nine young cochlear implant users, conjectured that children who received their cochlear implant by the age of 12 months (n= 27) would perform better than children fitted later (e.g. between the ages of 12 and 18 months; n= 42). They also hypothesized that in the long term, these young children with hearing impairment will perform within the age appropriate range of normally hearing peers by the age of 4;6. They found that children identified under the age of one benefitted from receiving their cochlear implant earlier, in that 85% of the children achieved age appropriate receptive language and 77% attained expressive language within normal limits (i.e. between -1 to +1 SD) for their age by the age of 4;6. This is in comparison with the 12 to 18 months cohort, whereby only 60% of the children achieved scores within normal limits on the receptive test of the Pre-school Language Scales-3 and 57% on the expressive language test (See Table 2.5).

Table 2.5 ***Proportion of children with hearing impairment who achieve age appropriate abilities by the age of 4;6 years in the study by Nicholas and Geers (2013)***

	Received a cochlear implant under 12 months (n=27)	**Received a cochlear implant between 12 and18 months (n= 42)**
Receptive Language	85% achieved age appropriate language	60% achieved age appropriate language
Expressive Language	77% achieved age appropriate language	57% achieved age appropriate language

When evaluating the group as a whole (i.e. all children in the study were fitted with a cochlear implant under 18 months), 47 of the 69 (i.e. 68%) children with hearing impairment achieved scores on the Pre-school Language Scales-3 equal to that of the their normally hearing peers by the age of 4;6. It would be of value to follow longitudinally the group of children with hearing impairment who exhibited delayed language in the pre-school years, as this research may support clinicians in understanding the developmental trajectory that this cohort of children with hearing impairment display. Yoshinago-Itano (2006) suggested that early identification (i.e. under the age of six months) and intervention may not be, in itself, enough to enable children with hearing impairment to achieve language similar to their normally hearing peers by the age of 3;0 to 4;0 years.

In summary, researchers in the field of hearing impairment have identified patterns of spoken language development in orally educated children with hearing impairment. This includes that expressive vocabulary develops faster than receptive vocabulary and that longer cochlear implant/hearing aid use is required in order to achieve higher level language skills that relate to grammatical and morphosyntactic development. Researchers have also come to a consensus that the younger children are when they receive their hearing aids or a cochlear, the better spoken language outcomes they will possibly achieve. That is to say that, children fitted with a cochlear implant under the age of 2;0 develop more age appropriate vocabulary and language abilities than those fitted at older ages. However, even in situations where there is intensive parental and educational support, early device fitting and consistent hearing aid or cochlear implant use, some children with hearing impairment do not acquire spoken language equal to their normally hearing peers by the time they reach UK school entry age.

2.8 Children with hearing impairment and additional language learning difficulties

The diagnosis of specific language impairment is often applied to children who display notable difficulties in receptive or expressive vocabulary and language, including phonology, grammar, syntax and pragmatics, but without additional developmental, neurological or cognitive difficulties (Leonard et al., 2007). The population of children with specific language impairment is heterogeneous in nature, as the severity and pattern of deficits vary according to each child (Bishop, 2004). Researchers in the field of hearing impairment have hypothesized that there may be additional language learning difficulties, such as specific language impairment that co-exist in some children with hearing impairment (Briscoe et al., 2001; Gilbertson and Kamhi, 1995; Hansson et al., 2004; Hansson et al., 2007; Norbury et al., 2001). Researchers have primarily compared the language and memory abilities of children with mild to moderate hearing loss to those of children with specific language impairment. Their findings suggest that children with mild to moderate hearing impairment outperform the children with specific language impairment with regard to finite verb morphology (Norbury et al., 2001), verbal working memory and sentence comprehension (Hansson et al., 2004). A proportion of children with mild to moderate hearing loss may also exhibit similar deficits in phonological short-term memory, vocabulary, morphology and syntax as children with specific language impairment (Briscoe et al., 2001; Hansson et al., 2007). However, their abilities are not as delayed as those of children with specific language impairment and the difficulties that children with hearing impairment display may in part be due to coming late to spoken language learning as a result of their hearing impairment.

Children with hearing impairment not only have a “different starting point” than other normally hearing children, but they also follow a different pattern of spoken language development (See Sections 2.6 and 2.7). How children with hearing impairment access spoken language (i.e. through hearing aids or cochlear implants) and “the way in which” they learn spoken language also differentiates them from their normally hearing peers, including children with specific language impairment. That is to say, that the signal that is provided by hearing devices is considerably different and impoverished in comparison to the normally developing auditory system, and researchers have found that cortical reorganization takes place due to the auditory deprivation that children with hearing impairment experience (See Section 2.2.1). In addition, children with hearing impairment require more exposures to language and a richer language learning environment in order to acquire new vocabulary, grammatical morphemes and syntactic structures than their normally hearing peers. This is due to the limited experience of incidental listening that children with hearing impairment encounter, as they are unable to perceive speech clearly in multi-talker environments and in background noise (Cole and Flexer, 2011). These differences in auditory and spoken language learning experience distinguish children with hearing impairment from their normally hearing peers and children with specific language impairment. The above factors along with the disputes around the specific language impairment terminology and diagnosis (See Chapter 1, Section 1.4), have influenced the decision making regarding the terminology used in this thesis to describe the population of children hearing impairment who are experiencing substantial difficulties in acquiring spoken language. Therefore, the term language learning difficulties (LLD) is used in this thesis, to differentiate the children with hearing impairment from normally hearing children and children with specific language impairment.

Few studies, however, have specifically targeted the population of children with hearing impairment with additional language learning difficulties. Hawker et al. (2008) focused upon six cochlear implant users, with a minimum of seven years of cochlear implant use, who displayed considerable language learning difficulties. They described this as disproportionate language impairment (DLI). These researchers paired six paediatric cochlear implant users with DLI with other cochlear implant peers, whose language development followed a more typical developmental trajectory. All the children were fitted with their cochlear implants between the ages of 1;8 and 6;5 years. The children were matched on aetiology, age of implantation and cochlear implant experience. Hawker et al. (2008) concluded that in fact all six children in the control group exhibited characteristics similar to specific language impairment with deficits in both language and phonological short-term memory, while the cochlear implant users with DLI displayed even poorer abilities in language acquisition and memory. They postulate however that the different educational settings (i.e. oral or total communication) could have influenced the children's ability to achieve on their battery of assessments, as sign language was not utilized during the administration of tests. It may also be noteworthy that Hawker et al.'s population of children with hearing impairment were much older when fitted with their device, and therefore there may be an influence of age of implantation on the development of their spoken language abilities. Drawing these and the above findings together, it is clear that an area that merits further research is the population of children with hearing impairment who exhibit poor spoken language outcomes.

2.9 Summary

Researchers continue to question why there is large variability in spoken language outcomes in children with hearing impairment. It has been found that orally educated children achieve better spoken language abilities than children who use total communication (See Section 2.3) and that early intervention and fitting of hearing aids/cochlear implants has a beneficial impact on language development (See Section 2.7.2). Nonetheless, there remain a proportion of children with hearing impairment who meet the above criteria and still do not achieve spoken language equal to that of their normally hearing peers (Boons et al., 2012; Caselli et al., 2012; Chilosi et al., 2013; Duchesne et al., 2009; Nicholas and Geers, 2013; Yoshinaga-Itano, 2003). Researchers are now investigating whether the difference in language development for some children with hearing impairment is associated with differences in cognitive processes such as memory ability. Chapter 3 will discuss the research findings in relation to both verbal and visual memory abilities in children with hearing impairment and how their memory abilities compare with their normally hearing peers.

Chapter 3 Memory and children with hearing impairment

3.1 Introduction

Chapter 3 begins with a discussion of two well-researched theories of memory: the capacity model and the multi-component model. It explores and justifies the choice of the multi-component model in the current research. Using this model, the chapter then briefly considers the implications of weaknesses in working memory in relation to language development and educational achievement. The chapter goes on to review the verbal and visual memory assessments most commonly utilized with children: the Working Memory Test Battery for Children (Pickering and Gathercole, 2001) and the Automated Working Memory Assessment (Alloway et al., 2007). The fourth part of the chapter outlines the ways in which verbal and visual short-term memory and working memory can be assessed. The chapter then examines the memory research in the field of paediatric hearing impairment with regard to verbal short-term memory, visual working memory and verbal rehearsal speed. Drawing on the literature reviews in Chapters 2 and 3, the final part of the chapter states the research questions pertinent to the current study.

3.2 Two theories of memory

Memory plays a vital role in educational achievement, as it underpins the capacity to learn and to acquire language (Alloway et al., 2009a; Archibald and Gathercole, 2006a). Short-term memory is often described as the ability to store verbal or visual information over short periods of time, without additional, competing cognitive demands. Working memory is defined as the limited capacity to store verbal or visual information temporarily for processing. It acts as a workbench or mental workspace for information that requires immediate attention and processing (Baddeley, 2012; Baddeley et al., 2009; Daneman and Carpenter, 1980; Just and Carpenter, 1992). The two theories that are being considered are the capacity theory and the multi-component theory of memory. The capacity model purports that working memory is domain general; a single limited-capacity system that does not incorporate separate systems for the storage of visual and verbal material. The capacity theory is thus a single component theory that proposes that there is a limited amount of available resources for working memory and they must be allocated to or shared between storage and processing (Daneman and Carpenter, 1980; Just and Carpenter, 1992). This model hypothesizes that the complexity of material to be processed will reduce the amount of capacity for storage. That is to say, when the demands of either processing or storage exceed the available capacity, there is an adverse effect on the amount of resources allocated to the other. Thus, storage abilities directly influence processing abilities and vice versa. This theory argues that children's improvements in the rate and efficiency of processing verbal or visual information result in developmental increases in working memory abilities.

The multi-component theory maintains working memory is comprised of a number of distinct subsystems with modality specific storage systems (Baddeley, 2003; 2012) (See Figure 3.1). Baddeley's model consists of "an orchestrator" responsible for attentional control and processing and co-ordinating both visual and verbal information, but also utilises domain specific subsystems that are responsible for short-term management of verbal and visual information. Baddeley's model allows for the individual examination of short-term memory and working memory across both verbal and visual domains. This in-depth examination is essential in the order to develop memory profiles for children with hearing impairment. Therefore, this model is the platform for the examination of memory abilities in this thesis, and the memory assessments used in the current study are based upon the structure of Baddeley's model. As such, Baddeley's model is discussed in more detail in the following sections.

Currently, the predominating model of working memory that researchers refer to in the literature is that of Baddeley (2000; 2003). This model has been utilized extensively in research with children with developmental disorders (Alloway and Gathercole, 2005; Alloway et al., 2009a; Archibald and Alloway, 2008; Archibald and Gathercole, 2006a; Archibald and Gathercole, 2006b). The multi-component model consists of the central executive, the two modality-specific subsystems (i.e. the phonological loop and visuo-spatial sketch pad) and the episodic buffer; a "multidimensional storage system" (Baddeley, 2003, p.189). The phonological loop's role is that of interpreting phonological information and creating temporary phonological representations that begin to decay after approximately 2 seconds. It is a limited capacity system, which is supported by an articulatory control process, whereby items may be refreshed through sub-vocal rehearsal. Sub-vocal rehearsal is when information, either verbal or visual, is repeated without overt vocalization in order to maintain it and keep the information from decaying (Baddeley, 2003; 2012). The visuo-spatial sketch pad's role is similar to that of the phonological loop, but in relation to visual and spatial information. For the purpose of this thesis, visual and spatial information are considered together. It is hypothesized that the episodic buffer temporarily binds visual and verbal information from the phonological loop and the visuo-spatial sketch pad with that from the long term memory into episodes (Baddeley, 2003; Baddeley, 2012). The episodic buffer is involved in the transfer of information back and forth from the short-term memory to the long term memory and has limited capacity of approximately four chunks by adulthood (Baddeley, 2003).

The central executive is involved in allocating attentional resources. It has an additional role of processing and co-ordinating information from either subsystem, allocating resources as well as managing and integrating information from within working memory and between working memory and long term memory. Baddeley's model (2003) defines working memory as a series of fluid systems that require only temporary use, but long term memory is characterized by more permanent "crystallised" knowledge. See Figure 3.1 for a visual representation of Baddeley's Working Memory Model (2003).

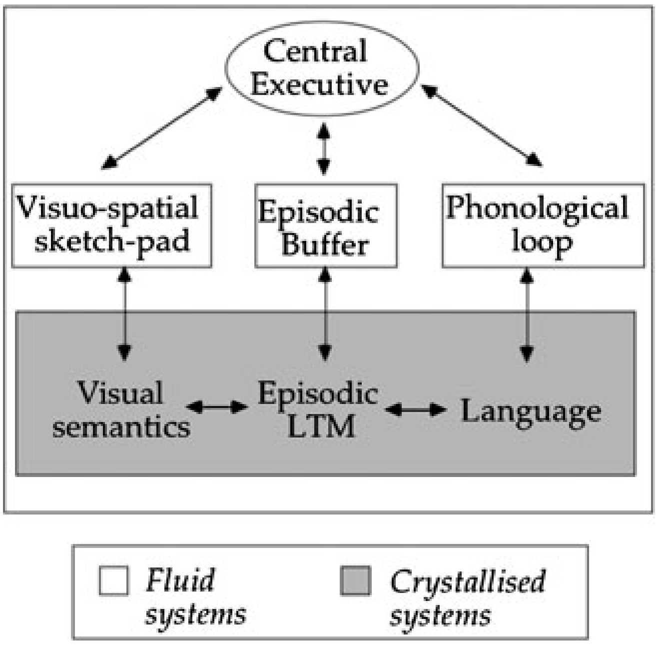

Figure 3.1 **Baddeley's Working Memory Model (2003)**

3.3 Relationship between language, memory and educational achievement

The phonological loop's functioning depends upon phonological and lexical representations in the long term memory. Thus, tasks that evaluate verbal short-term memory are indirectly assessing the efficiency of the phonological loop and the quality of representations in the long term memory. Phonological short-term memory, also termed verbal short-term memory, is claimed to support word learning and vocabulary and grammatical development (Adams and Gathercole, 2000; Archibald and Gathercole, 2006a; Gathercole, 1999; Gathercole et al., 1997b). It is important to clarify that a weakness in verbal short-term memory does not cause poor language development or inhibit the acquisition of language (Ebbels et al., 2012; Freed et al., 2012; Gathercole et al., 2005; Vance, 2008), as children can have impaired memory abilities and still exhibit age appropriate receptive vocabulary, language and reading abilities. However, if a child has a substantial weakness in verbal short-term memory, this may negatively impact upon their ability to function in an educational setting. For example, if a child has poor verbal short-term memory abilities the additional demands upon attention (i.e. central executive), of noise in a classroom environment for example, will contribute to further difficulties in learning vocabulary and recalling sentences. It is commonly recognised that working memory difficulties can adversely affect the development of language, literacy, mathematical skills (Hansson et al., 2004; Nittrouer et al., 2012; Nunes et al., 2009) and can have detrimental effects on school performance. The ability to remember information and act on it is crucial to a child's success in a classroom environment (Alloway et al., 2009a; Gathercole et al., 2006). That is to say, teachers give instructions and expect children to act upon them, whilst also completing other tasks. As part of a child's school day, simple everyday tasks, such as writing a sentence whilst also correctly spelling the words, involve working memory abilities (i.e. both memory and processing). Children with working memory difficulties are often described by teachers as having poor attention, not being able to follow instructions, not completing their work, and not able to remember simple tasks asked of them (Gathercole et al., 2006).

3.4 Assessment of memory

Verbal and visual short-term memory and working memory are assessed by using forward and backward digit recall, block design and listening recall. These tests feature in many psychological and language assessments. However, the focus for the current study is on the Working Memory Test Battery for Children (WMTB-C) (Pickering and Gathercole, 2001). The framework of this assessment is built on premises established by Baddeley and his working memory model (2003) (See Section 3.2 and Figure 3.1). That is to say, the afore-mentioned assessments evaluate the functioning of the phonological loop (i.e. verbal short-term memory), visuo-spatial sketchpad (i.e. visual short-term memory) and central executive functioning. The WMTB-C is standardized on typically developing children aged between 4;7 and 15;9 years and comprises nine subtests, which evaluate specific components of short-term memory and working memory. The WMTB-C measures both verbal and visual short-term memory, which involves only the temporary storage of either verbal or visual information. It also assesses working memory, which is the simultaneous storage and processing of information. Again, this information can also be verbal or visual.

The Automated Working Memory Assessment (AWMA) (Alloway et al., 2007) is a computerized development of the WMTB-C (Pickering and Gathercole, 2001) with an omission of one of the verbal short-term memory subtests and the inclusion of four additional subtests that measure visual short-term memory and working memory. The AWMA (Alloway et al., 2007) has been standardized on a larger population of children, adolescents and adults and provides normative data from the ages of 4 to 22 years. The benefit of AWMA is that it minimizes differences in testing administration, such as rate and intonation, which may have an impact upon performance (Alloway et al., 2007). However, for children with hearing impairment, using live voice when administering an assessment is recommended (Geers and Sedey, 2011). This is due to perceptual difficulties that children with hearing impairment have when listening to automated or recorded speech. Table 3.1 contains a complete outline of subtests for both memory assessments.

Recent studies have argued for the use of multiple measures of verbal short-term memory, as a way in which to further investigate and identify possible patterns of weaknesses in memory abilities in children with hearing impairment (Harris et al., 2013; Kronenberger et al., 2011; Pisoni et al., 2011). Whilst the current PhD study commenced prior to these publications, the recommendations from these researchers are addressed by this thesis. The following discussion will focus on the subtests utilized in the current study. (See Chapter 4, Section 4.11 for a detailed description of individual subtests used in the current research).

Table 3.1 ***Memory components of the Working Memory Test Battery for Children (WMTB-C) (Pickering and Gathercole, 2001) and Automated Working Memory Assessment (AWMA) (Alloway et al., 2007)***

Memory Components	Subtest	WMTB-C Subtests	AWMA Subtests
Verbal Short-term memory (Phonological Loop)	*Digit Recall	Yes	Yes
	*Word Recall	Yes	Yes
	*Non-word Recall	Yes	Yes
	Word List Matching	Yes	No
Verbal working memory (Central Executive)			
	*Backward Digit Recall	Yes	Yes
	*Listening Recall	Yes	Yes
	Counting Recall	Yes	Yes
Visual Short-term memory (Visuo-spatial Sketch Pad)			
	*Block Recall	Yes	Yes
	Mazes Memory	yes	Yes
	Dot Matrix	No	Yes
Visual working memory (Central Executive)			
	*Odd one out	No	Yes
	Mr X	No	Yes
	Spatial Recall	No	Yes

*These subtests are used in the current study and are described in more detail in Chapter 4, Section 4.11 and Tables 4.4 and 4.5.

3.4.1 Phonological loop/verbal short-term memory subtests

Digit Recall

Pickering and Gathercole (2001) utilized four subtests to assess the functioning and integrity of the phonological loop in their assessment, the Working Memory Test Battery for Children (WMTB-C). Alloway et al., (2009b) discussed the functioning of the phonological loop in terms of verbal short-term memory and makes use of three subtests as a way in which to evaluate the functioning of the phonological loop. The ability to recall correctly increasing numbers in a Digit Recall task is said to evaluate verbal short-term memory (Pickering and Gathercole, 2001).

Digit Recall is also used synonymously for “forward digit recall.” The Digit Recall subtest from the Wechsler Intelligence Scale for Children 3rd edition (Wechsler, 1991) is commonly utilized in the assessment of children with hearing impairment. This test asks children to correctly recall digits in the same order as they are spoken to them. It is important to note that numbers themselves are extremely meaningful and familiar. They tap semantic and lexical knowledge, which may support recall or involve the functioning of the visuo-spatial sketchpad. Numbers in themselves may however be a separate semantic category and may not provide the insight into the semantic functioning of other categories which require more semantic knowledge, such as words. Therefore, Digit Recall, as a test used in isolation, may be a less sensitive predictor of verbal short-term memory abilities than other verbal short-term memory tests such as Non-word Recall or Word Recall (Gathercole and Baddeley, 1996).

Non-word repetition

Traditionally, non-word repetition tasks that increase in syllable number have been utilized to investigate the efficiency of the phonological loop and functioning of verbal short-term memory (Gathercole, 1999). The most frequently utilized Non-word Recall tests are the Children’s Test of Non-word Repetition (CNRep, Gathercole and Baddeley, 1996) and Non-word Repetition Test (NRT, Dollaghan and Campbell, 1988) and subtests from the Developmental Neuropsychological Assessment (NEPSY, Korkman et al., 1998). These assessments ask listeners to repeat nonsense words (from audition alone) that increase in syllable length. Non-word Recall tasks demand that children listen to and recall novel word patterns. The ability to recall non-words relies heavily upon the children's previous experience of word learning and lexical knowledge. This task is complex in that it requires encoding of new phonological information, maintenance of these novel structures and accurate repetition of the target. Researchers have found that Non-word Recall abilities, utilizing traditional Non-word Recall tests, are often significantly correlated with vocabulary development and language acquisition in young children aged approximately 4 years old (Adams and Gathercole, 2000; Gathercole et al., 1997b). Thus, the inability to repeat correctly multisyllabic nonsense words of 3 or more syllables is considered to be a possible indicator of language impairment in early childhood (Archibald and Gathercole, 2006a; Bishop, 2006; Bishop et al., 2004; Bishop et al., 1996; Weismer et al., 2000). However, there is some theoretical discussion as to whether vocabulary ability and Non-word Recall are as strongly correlated in older children (Botting and Conti-Ramsden, 2001). Simkin and Conti-Ramsden (2001) found that 10 year old typically developing children perform at ceiling on traditional tests of Non-word Recall. The benefit of utilizing a single syllable non-word recall task such as the one included in the AWMA (Alloway et al., 2007 and WMTB-C (Pickering and Gathercole, 2001), is that it may be more sensitive to developmental changes and identification of language learning difficulties in older children.

The difficulties with the traditional Non-word Recall tests for children with hearing impairment are two-fold. Due to their hearing loss, children may have difficulty in perceiving and discriminating the subtle differences in speech sounds in multisyllabic non-words, especially if these tests are administered using recorded speech, which provides a poorer quality of sound than live voice. Briscoe et al. (2001) support this assertion although they conjecture that these perceptual difficulties may also occur in both short and long non-words. Secondly, the children with hearing impairment may also have co-existing articulation difficulties, which could affect their ability to correctly repeat multisyllabic non-words. Therefore the added value of a single-syllable CVC Non-word Recall test in both the WMTB-C (Pickering and Gathercole, 2001) and the AWMA (Alloway et al., 2007) is that these possible confounding variables are addressed.

Word recall

Verbal short-term memory may also be evaluated using Word Recall. This task provides additional information that the Digit Recall and Non-word Recall subtests may not illuminate, as word recall accesses greater amounts of lexical and semantic knowledge and the storage of words in the long term memory. The Word Recall test evaluates the efficiency with which words are encoded or stored, as well highlighting that the quality of stored phonological (e.g. the stored phonetic structures of spoken words) and lexical representations (e.g. the stored form of words in the long term memory/lexicon). Mainela-Arnold and Evans (2005) found that degraded lexical representations in words were the fundamental difficulty in children with language impairment, aged between 8;4 and 12;4 years, when completing the Gaulin and Campbell Task (1994), Competing Language Processing Task (CLPT) (See Section 3.4.3). Therefore, difficulties with the Word Recall task may relate to a multitude of variables (e.g. word frequency, word familiarity, word length effect), as well as the functioning of the phonological loop. These factors that affect word recall are discussed below. Word familiarity and word frequency enhance word recall abilities. That is to say, words that are highly familiar and words that are more frequently used in everyday speech are easier to recall than less familiar words (Baddeley, 2012; Gathercole et al., 2001; Majerus and Linden, 2003). The effect of word length influences recall ability, which practically means that words that are shorter are easier to recall due to less demands upon sub-vocal rehearsal (Baddeley, 1997). Phonologically similar words (i.e. words that sound alike) are also more difficult to recall due to lasting traces from previous target words. The additional benefit of the Word Recall subtest from the WMTB-C is that the target words are single syllable and CVC in structure, which address previously mentioned issues in the above section.

3.4.2 Visuo-spatial short-term memory

The Block Recall subtest of the WMTB-C evaluates visuo-spatial short-term memory and the functioning of the visuo-spatial sketch pad. It is often used alongside other psychological assessments, as the administration of the Block Recall subtest test is not reliant upon comprehension of vocabulary or spoken language. This task requires children to point to blocks in the correct order after observing the administrator do so. It is utilised in the current study in order to evaluate if there are generalized memory difficulties, which occur in both the visual and verbal domains.

3.4.3 Verbal working memory and visual working memory

The verbal working memory subtests primarily assess the functioning of the central executive, which controls attention, as well as co-ordinating and directing other components of the system. Weakness in verbal or visual short-term memory may have some impact upon the functioning of the central executive, as its role as co-ordinator may possibly be compromised by the weakness in the phonological loop or visuo-spatial sketchpad (Baddeley, 2012). However, this is not to say verbal short-term memory deficits will always affect verbal working memory abilities. This is demonstrated by Alloway et al.'s, (2009b) study of children with different developmental disorders. They found that children with Autistic Spectrum Disorder exhibited verbal working memory abilities equal to that of their peers, but verbal short-term memory abilities more than one standard deviation below the mean . The premise behind evaluating the functioning of the central executive across both visual and verbal modalities is to examine whether there are generalized processing deficits, which originate from the poor functioning of the central executive or whether deficits are localized to verbal or visual short-term memory.

Verbal working memory

Assessing verbal working memory indirectly evaluates the functioning of the central executive. That is to say that verbal working memory assesses the ability to temporarily remember (i.e. store) verbal information whilst also manipulating it (i.e. processing). The Listening Recall task from the WMTB-C and AWMA is a subtest that asks the listener to validate the truthfulness of a statement, as well as recalling the last word in that sentence. Other researchers have utilized similar tasks in order to assess verbal working memory. Gaulin and Campbell (1994) devised the Competing Language task which is similar to the Listening Recall subtest described above. Backwards Digit Recall is also considered a valid test of verbal working memory (Montgomery, 2000a; Pisoni et al., 2011). The task requires that the participant listens to a series of numbers and then repeats them in the reverse order, thus using both storage and processing to complete the task. Researchers argue that verbal working memory is strongly correlated with language development as it dependent upon knowledge that is already stored in the long term memory (Hansson et al., 2004; Harris et al., 2011; Lina-Granade et al., 2010; Montgomery, 2000b; Montgomery, 2002; Montgomery, 2006).

Visual working memory

The visual working memory subtest form the also examines the visuo-spatial sketch pad and the effectiveness of the central executive, but uses only visual information. The Odd One Out subtest from the computerized memory assessment, the AWMA (Alloway et al., 2007), has three pictures of shapes on the computer screen that have no identifiable name. Two of the shapes match. The participant is asked to identify the "odd one out" and then identify where the location of that shape was in the correct order after the screen becomes blank. Again, this test does not rely on verbal short-term memory, as the shapes are not "nameable" such as a triangle, square etc., and the participant only needs to point to different boxes where shapes were located on the computer screen in the correct order. This test is utilised in the current study as a way in which to assess central executive functioning and whether there are generalized processing difficulties.

3.5 The use of WMTB-C and AWMA with other paediatric populations

The WMTB-C and AWMA have been utilized with other populations of children with developmental disorders, such as developmental co-ordination disorder, Attention Deficit Hyperactivity Disorder (ADHD), specific language impairment and Asperger's Syndrome (Alloway et al., 2009b; Archibald and Alloway, 2008; Archibald and Gathercole, 2006a; Archibald and Gathercole, 2006b; Freed et al., 2012). Researchers have made use of the multiple subtests in the WMTB-C and AWMA that assess performance of each component of Baddeley's Working Memory Model, as a way in which to define further the strengths and weaknesses in memory abilities in these different cohorts of children.

Alloway et al. (2007; 2009) demonstrated that there are very distinctive memory profiles for children with specific language impairment, ADHD, developmental co-ordination disorder and Asperger's syndrome. Children with specific language impairment display difficulties in both verbal short-term memory and working memory, but average abilities in visuo-spatial short-term memory and working memory. Children with ADHD have deficits in visuo-spatial short-term memory and working memory, but low average scores in the verbal domain. These profiles compare with children with ADHD who display verbal short-term memory abilities well within normal limits, but poorer scores in verbal working memory and visuo-spatial short-term memory and working memory. These profiles again differ from children with Asperger's Syndrome who present with a deficit in verbal short-term memory, but average abilities in all other areas of verbal and visual short-term memory and working memory (See Table 3.2).

Table 3.2 ***Verbal and visual short-term memory and working memory profiles from Alloway et al. (2009b)***

	SLI (n=15)	**ADHD (n=83)**	**DCD (n=55)**	**AS (n=10)**
Digit Recall (DR)	84.33	94.73	82.55	85.70
Word Recall (WR)	83.93	98.81	90.24	76.40
Non-word Recall (NWR)	82.93	103.08	93.62	80.10
Backward Digit Recall (BDR)	82.20	89.24	85.45	90.70
Listening Recall (LR)	85.67	90.65	89.15	94.10
Block Recall	92.20	87.99	80.20	86.60
AWMA Odd One Out	95.80	88.25	85.84	97.60

SLI = Specific Language Impairment AS= Asperger's Syndrome

DCD= Developmental Co-ordination Disorder

ADHD=Attention Deficit Hyperactivity Disorder

This detailed profiling of memory abilities has yet to be conducted in children with hearing impairment. By identifying the strengths and weaknesses in verbal and visual memory in children with hearing impairment, clinicians and teachers may have a greater understanding of their difficulties and be better able to support their language development and educational achievement.

3.6 Research in hearing impairment and memory

Researchers have found that that children with hearing impairment exhibit different memory abilities from their normally hearing peers (Casserly and Pisoni, 2013; Fagan et al., 2007; Hansson et al., 2007; Harris et al., 2011; Pisoni et al., 2011; Willstedt-Svensson et al., 2004). Researchers have attributed the cause of these differences to the degraded signal and different auditory experience that children receive via hearing aids or cochlear implant (See Chapter 2, Section 2.2.1). It is hypothesized that this experience has a detrimental effect on their development of clear, well defined phonological representations (Diller, 2010; Harris et al., 2013; Nittrouer et al., 2013; Pisoni et al., 2011; Wass et al., 2010). The further identification of the differences in verbal short-term memory and working memory in children with hearing impairment may provide researchers with an explanation as to why there is large variability in spoken language outcomes in this population of children.

3.6.1 Outcomes in verbal short-term memory and working memory in children with hearing impairment

A number of researchers have investigated verbal short-term memory in children with hearing impairment through the use of traditional non-word repetition tests that increase in syllable length and therefore increased demands on verbal short-term memory (Casserly and Pisoni, 2013; Dawson et al., 2002; Lina-Granade et al., 2010; Pisoni and Cleary, 2003; Willstedt-Svensson et al., 2004). The performance on the multisyllabic non-word repetition task, CNRep (Gathercole and Baddeley, 1996) has a strong correlation with receptive vocabulary, reading, and language development in children with hearing impairment (Dillon et al., 2004; Hansson et al., 2004; Willstedt-Svensson et al., 2004). However, few researchers in the field of paediatric hearing impairment have utilized multiple tests that evaluate each component of verbal and visual short-term memory and working memory (Diller, 2010; Wass et al., 2010) (see Table 3.3 for information regarding the research in memory and hearing impairment).

Diller (2010) evaluated verbal short-term memory (Digit Recall, Word Recall and Non-word Recall) and articulation rate in twenty-four children with cochlear implants who were orally educated. He found no significant difference between children with hearing impairment and normally hearing groups, with reference to the recall of words, forward digit recall or articulation rate. He suggested that there may be a positive effect of age of fitting of their device (all children received their cochlear implant by the age of two) and achieving age appropriate results in Digit Recall, Word Recall and articulation rate. However, the recall of non-words in children with hearing impairment was much poorer. It is unclear whether these target non-words were single syllable or multisyllabic in nature. If the stimuli were multisyllabic non-words, the children with hearing impairment may only be demonstrating that they are having perceptual difficulties with the multisyllabic non-words. Conversely, Diller's (2010) results may reflect the difference in the quality of the information processed by the children with hearing impairment. This later hypothesis is further supported by their language results, which demonstrated a weakness in comprehension of sentences, sentence recall and grammar. Interestingly, the children with hearing impairment in this study did exhibit similar mean length utterance and syntactic structures, such as verb tense and noun verb agreement, as their normally hearing peers.

Wass et al., (2010) examined the visual working memory and verbal short-term memory and working memory skills of thirty-four children with hearing impairment (See Table 3.3). They found that children with hearing impairment had visual working memory abilities commensurate with those of normally hearing peers, but only 33% had verbal working memory abilities within the typical range. However, verbal short-term memory was poorer still, with only 12% of children with hearing impairment functioning similarly to that of their normally hearing peers. Wass et al., (2010) also discovered that verbal recall weaknesses were less pronounced with real words than non-words. Harris et al., (2013) longitudinally evaluated the verbal short-term memory and working memory abilities of sixty-six children aged between 8;0 and 16;0 years old using both forward and backward digit recall tasks. They found that forward digit recall was an accurate predictor of successful language development. However, they concluded that children with hearing impairment failed to catch up over time with normally hearing peers. It is worthy of note that only ten children in this study were fitted with their implant under the age of two and nearly half of the sixty-six children in the study (n= 27) received their cochlear implants between the ages of 4;0 and 8;0 years. There may have been differences in abilities between these two cohorts of children if further examined.

3.6.2 Digit recall, verbal rehearsal speed and articulation rate

Researchers in the field of paediatric hearing impairment acknowledge that there is a strong relationship between verbal rehearsal speed, short-term memory, working memory and language development (Harris et al., 2011; Pisoni et al., 2011; Pisoni and Cleary, 2003). The process of rehearsal is argued to be an accurate way in which to measure the efficiency of phonological representations maintained in the short-term memory and may be indicative of a weakness in children with hearing impairment's ability to use verbal rehearsal (Burkholder and Pisoni, 2003; Dillon et al., 2004). It is hypothesized that speed at which a child can repeat words (e.g. articulation rate) will have an impact upon their short-term memory abilities. Diller (2010) found that articulation rate at 6;0 years old in children with hearing impairment was equal to that of normally hearing children, however the children with hearing impairment still exhibited poorer verbal short-term memory abilities when recalling non-words. Stiles et al. (2012) also discovered that children with mild to moderate hearing impairment displayed articulation rates and forward digit recall abilities similar to that of their normally hearing peers, but that they had delayed receptive vocabulary. Therefore, one cannot assume that age appropriate articulation rate ensures verbal short-term memory and/or vocabulary abilities will be within the normal limits.

Pisoni and Cleary (2003) reported that verbal rehearsal speed was positively correlated with spoken language outcomes in their population of 180, 8 and 9 year old cochlear implant users. In a follow up study approximately 8 years on, Pisoni et al. (2011) examined the verbal rehearsal speed and digit recall abilities (forward and backward) of 108 adolescent cochlear implant users. The study comprised 53 teenagers who used total communication as their main mode of communication and 55 pupils who were oral. They found that verbal rehearsal abilities had improved in the teenage cochlear implant users (i.e. 16 year olds) and that 55% of those teenagers demonstrated verbal rehearsal abilities similar to that of their normally hearing peers. Pisoni et al. (2011) also found that Forward Digit Recall at ages 8 and 9 was positively correlated with future linguistic functioning in the high school years. Interestingly, Backwards Digit Recall scores were poorer in adolescence, with 23% being below average at 8 to 9 years increasing to 38% in adolescence. With regard to forward digit recall, 75% were below average at ages 8 and 9 decreased to 58% by adolescence. It is notable that 95 out of 108 (88%) teenagers exhibited age appropriate language skills by age of 16, and of the thirteen pupils who did not achieve language abilities commensurate to that of their normally hearing peers, nine used total communication as their primary mode of communication. It is also important to highlight that the adolescents with hearing impairment who returned for the follow up study had higher scores in their speech perception, speech intelligibility and language assessments at age 8 to 9 compared with the 72 teenagers who were lost to follow up. The findings by Pisoni et al. (2011) demonstrate that age appropriate verbal rehearsal abilities and Forward and Backward Digit Recall abilities were not necessary in order for the teenagers to achieve language abilities equal to that of their normally hearing peers.

In summary, researchers have identified that children with hearing impairment have slower verbal rehearsal abilities and are poorer at multisyllabic non-word and digit recall, but may still demonstrate word recall and language abilities equal to that of their normally hearing peers. These findings should be considered in light of three issues. Firstly, the Non-word Recall task has been correlated with vocabulary development in children younger than the age of four and researchers have found that this assessment is less sensitive in older children (Simkin and Conti-Ramsden, 2001) and therefore this task may only demonstrate that the task in itself is difficult for children with hearing impairment. Secondly, the Non-word Recall task taps other skills such as encoding and maintenance of information, as well as lexical knowledge and therefore difficulties with this task may be as a result of other factors such as poor quality lexical representations in the long term memory. Finally, many researchers have included subgroups of children with hearing impairment (e.g. oral and total communication) as one group and did not differentiate between their results or treat them as two separate groups and therefore the relationship between difficulties with Non-word Recall may be strongly related to communication mode (See Table 3.3 for an overview of the research). It remains to be seen if there is a strong correlation between memory difficulties and age of fitting of device. If weaknesses in memory abilities occur in children with hearing impairment irrespective of age of fitting of hearing device, then researchers can conclude that memory difficulties are not positively influenced by the early fitting of hearing aids or cochlear implants.

Table 3.3 ***Research in both hearing impairment and memory***

Memory and hearing impairment research	Sample characteristics	Hearing Loss or CI	Commun. mode	Measure	Comments
Hansson et al. (2004)	HI n= 18 Ages: 9;1-13;3 SLI n= 27 Ages: 8;6-11;4 NH n = 38 Ages: 9;5-12;4	Mild to moderate	Oral	Verbal STM (NWR) Verbal WM (Gaulin & Caplin Task)	CHI performed better than SLI group on language comprehension, complex WM and novel word learning. No significant differences were found between the groups on NWR. Swedish study.
Pisoni and Cleary (2003)	HI n = 176 Duration of CI use variable NH = 45 Ages 8-9 years	CI (between ages 1.8 and 5,4 years)	Oral and T/C	Verbal STM (FDR) Verbal WM (BDR) Verbal Rehearsal Speed	Oral children had longer FDR. T/C children exhibited slower verbal rehearsal speed that oral CHI. American study

Hawker et al. (2008)	HI n = 6 with LLD HI n = 6 more typically developing Ages = 10;6-14;6 Duration of CI use = 7;8-10;8	CI (CI between the ages of 1;8 and 6;5 years)	Oral and T/C	Verbal STM (NEPSY:NWR and FDR)	All children exhibited considerable delays in verbal STM. British study
Waas et al. (2010)	HI n = 34 Ages 5;7-13;4 NH = 120	CI	Oral	Verbal STM (NWR and Word Recall) Verbal WM (Sentence completion with final word recall) Visual WM (Matrix span)	Visual WM abilities within normal limits of NH peers. 33% of CHI had WM abilities within normal range; Verbal STM was weakest with only 12% of CHI functioning equivalent to NH peers. Phonological problems less pronounced with real words. Swedish study.
Diller (2010)	HI n = 24 Hearing age of 4 years; CA age 6 or	CI	Oral	Verbal STM (FDR, Word Recall and Non-word Recall)	Memory performance accounted for 43.8 % of the variance of children's linguistic performance. A

	younger NH n = 24			Articulation rate	German study.
Lina-Grenade et al. (2010)	HI n = 17 Ages 7-16 Duration of CI use a minimum of 4;9 years	CI (between ages 2-5 years)	Oral and T/C	Verbal STM (Word recall) WM Index	WM strongly correlated with language development. Deficits in WM memory may be as a result of delayed auditory input or as a result of the HI itself. Visual WM average for CHI.
Harris et al. (2011)	HI n= 110 Ages 3-15 years Duration of CI use at least 2 years	CI	Oral = 74 % T/C = 33%	Verbal STM (FDR) Verbal WM (BDR)	Longitudinally evaluated developmental trajectories. Rate of verbal STM and WM may influence language development. American study
Stiles et al. (2012)	HI n = 18 NH = 28 Ages : 6-9	Mild to moderate	Oral	Verbal STM (FDR) Articulation rate	CHI had digit recall abilities and articulation rates similar to NH Group. Correlation between smaller vocabulary size and poorer STM for CHI. American study

Pisoni et al. (2011)	HI n= 108	CI (between ages 1.8 and 5,4 years)	Oral= 55 T/C= 53	Verbal STM (FDR) Verbal WM (BDR)	Follow on study after 10 years. Children improved in verbal STM (FDR) by high school. BDR did not improve. FDR scores strongly associated with SL outcomes in high school. American study
Harris et al. (2013)	HI n = 66 Ages: n=10 implanted between 1-2 years n= 13 implanted between 2-3 years n= 18 implanted between 4-6 years n = 9 implanted between 6-8 years Testing age= 8-16 years	CI	Oral and T/C	Verbal STM (FDR) Verbal WM (BDR)	Longitudinal study utilizing endpoint data. FDR is accurate predictor of successful language development. American study

Casserly and Pisoni (2013)	HI n = 52 Fitted with CI by 5;0 Time 1 assessed at ages 8 to10 Time 2 assessed at ages 16 to18 years	CI	Oral and T/C	NWR	Early NWR abilities predicts late language development. Study participants are from previous studies (i.e. Pisoni et al., 2011). American study

CHI = Children with hearing impairment

FDR = Forward Digit Recall

Verbal STM = Verbal short-term memory

HI = Hearing impairment

Commun. Mode = Communication mode

BDR = Backwards Digit Recall

DR = Digit recall

Verbal WM = Verbal working memory

NH = Normally hearing

SL = Speech & Language

NWR = Non-word Recall

CI = Cochlear Implant

SLI = Specific language impairment

3.7 Hearing impairment, cochlear implants and language learning difficulties

There are few studies which have specifically investigated children with hearing impairment and additional language learning difficulties. One example is that of Hawker et al. (2008) who focused upon six cochlear implant users who were fitted with their device between the ages of 1;8 and 6;5 and who displayed major difficulties in spoken language learning. They compared them with six other cochlear implant users whose language development followed a more typical developmental trajectory. The children were matched on aetiology, age of implantation and cochlear implant experience. Hawker et al. (2008) found that non-word repetition, using the NEPSY non-word repetition subtest, (Korkman et al., 1998) was an area of deficit for both the Control cochlear implant group and the cochlear implant group with substantial language difficulties. They concluded that all of the six children exhibited disproportionate language impairment (DLI) and had severe language impairment and phonological short-term memory difficulties. They also hypothesized that the control group exhibited characteristics similar to children with specific language impairment. It may be conjectured that the late fitting of the cochlear implant for many of the children in both the control group and DLI cohort, had a detrimental effect on their language learning and verbal short-term memory abilities. Thus, their poor performance and the language measures are as a result of auditory and linguistic deprivation. These results may also been influenced by the modality in which the assessments were administered, in that speech alone was utilized. That is to say that five out of the six children in the DLI group and two out of six children in the Control group were in a total communication educational environment and would have benefitted from the use of sign language during testing. It is also important to highlight that this study did not investigate visual short-term memory or working memory, which would have demonstrated whether this population of children with hearing impairment exhibited generalized memory difficulties.

3.7.1 Ways in which to manage verbal short-term memory and working memory difficulties

The following section discusses ways in which researchers and professionals have endeavoured to develop and improve verbal short-term memory and working memory abilities in children with and without hearing impairment.

Strategies to manage short-term memory and working memory difficulties

Researchers have recommended ways in which compensatory strategies can be utilized in the management of verbal short-term memory and working memory difficulties (Gathercole and Alloway, 2008; Vance, 2008; Vance and Mitchell, 2005). These strategies are typically included as part of the educational support and therapeutic input for many children with hearing impairment, as consequence of their hearing loss (Cole and Flexer, 2008; Cole et al., 1992). Children with hearing impairment do not benefit as normally hearing children do from over-hearing, incidental language learning and hearing in noise. Given this reduced auditory experience, the quantity and quality of spoken language input that children with hearing impairment require needs to be more intensive. These techniques are discussed below with reference to children with hearing impairment.

<u>Slower rate</u>: Children with hearing impairment benefit from a slower rate of delivery and more pauses to allow for processing time. This allows them to use their knowledge of language and the context of the conversation to try and “fill in the gaps” in the message that may not have been heard as a result of background noise.

<u>Emphasis</u>: The term “highlighting” is frequently used in relation to children with hearing impairment. This is a technique that allows easier access to key words that may be unfamiliar or are key words to be learned. In practice, this means that the speaker says the word or phrase slightly louder, slightly longer and with more variation in the pitch. For example, “Your shoe is on the **Big chair**.”

<u>Chunking</u>: Information is often chunked into manageable pieces for children with hearing impairment, which reduces demands upon memory and processing. For

example, “Get your **coat, wellies and hat**.” In comparison to “Get your coat from the kitchen, your wellies from the porch and the dog has your hat.”

Introduction of vocabulary & concepts: When introducing new vocabulary, it is recommended that new words are “linked” with a familiar known word. For example, “Give me the **large** ball, yes the **big** one.”

Reducing demands: In order to reduce demands upon memory and processing, familiar vocabulary should be used when developing new syntactic structures or when engaged in a more cognitively demanding task. For example, when retelling a story, which requires the sequencing of events, using pictures and familiar vocabulary will enable the children with hearing impairment to be more successful at this task.

Provide visual support: As a result of their hearing impairment, children are commonly exposed to additional visual support (e.g. sign language, pictures). Further examples specific to supporting memory weaknesses in children with hearing impairment are the use of paper and pencil to record key information or new vocabulary, and the use of counters or number lines during lessons as a way in which to reduce demands upon memory.

Memory training programmes

The research findings in Section 3.6 support the hypothesis of poor verbal short-term memory and working memory abilities in children with hearing impairment. These findings may be one way in which to explain the large variability in spoken language outcomes in this population of children. The clinical implications of these findings have initially been addressed by developing training programmes to strengthen verbal short-term memory and working memory. Kronenberger et al. (2011), for example, targeted nine paediatric cochlear implant users in their study, which investigated the long term effects of the five week computerised Cogmed Working Memory training programme. The Cogmed exercises focus upon practising tasks (e.g. games on the computer) that require the use of verbal and visual short-term memory and working memory skills. Kronenberger et al. (2011) found that while there was a small improvement in verbal short-term memory at the one-month review, this progress was not maintained beyond the initial phase of the study. Sentence repetition, however, continued to show improvement six months post intervention. Nunes et al. (2014) also examined the effectiveness of working memory training programmes for children with hearing impairment using a game-based intervention. Their study compared two groups of children with hearing impairment aged between 5 and 11 years old with hearing loss ranging from moderate to profound. The intervention group (n = 73) was matched with the control group (n = 77) according to severity of hearing loss. The primary aim of the study was to utilize the children's strengths in visual memory to develop strategies to manage phonological information more efficiently. The intervention programme consisted of two activities, teacher-led games and web-based (computer) games. The teacher-led games focused upon developing verbal rehearsal strategies. The teacher modelled verbal rehearsal for the child to observe and encouraged him/her to use this strategy when playing the games. The games focused upon combining visuo-spatial information with verbal strategies to enhance recall abilities. The web-based games enabled the children to practise the visuo-spatial rehearsal strategies that they had learned with the support of their teacher. The stimuli used consisted of colours, numbers, animal names, words and letters of the alphabet. Nunes et al. (2014) found a significant improvement in scores between the intervention group relative to the control group. They comment that these improvements could not solely be attributable to improvements in working memory, but attentional control as well. This study did not evaluate whether this improvement was sustained or if there was a positive impact upon educational achievement or language learning.

3.7.2 Other avenues to explore

Researchers in the field of paediatric hearing impairment are seeking to address the needs of the substantial significant numbers of children with hearing impairment who do not achieve age appropriate language despite intensive input and early fitting of their hearing aids or cochlear implants. This process has involved the extensive examination of the memory abilities in children with hearing impairment. Given that deficits in memory for this population of children may be attributable to difficulties in either storage or processing of verbal information, further investigation into these possible areas of deficit has been a recommendation from the recent literature (Casserly and Pisoni, 2013; Harris et al., 2013; Nittrouer et al., 2013; Pisoni et al., 2011; Stiles et al., 2012). Nittrouer et al. (2013) in particular examined whether problems in verbal short-term memory and working memory were due to difficulties in processing or in storage. They investigated the memory abilities of fifty children with cochlear implants and forty-eight normally hearing children, who were aged eight years. They utilized rhyming nouns, non-rhyming nouns and non-rhyming adjectives as stimuli. They evaluated these targets in relation to recall accuracy and response rates. Their results demonstrated that reduced storage capacity did not influence processing and vice versa. That is to say that, they found that working memory development is not atypical in children with hearing impairment, but that memory deficits were due to storage only and not processing. One of the recommendations from their study includes the specific targeting of semantics and syntax in therapeutic contexts, as a way in which to support storage in working memory. This future area of research would provide speech and language therapists and educationalists with the much needed evidence base regarding these children's therapeutic needs.

3.8 Summary

In summary, some children with hearing impairment may exhibit weakness in verbal short-term memory and working memory, but demonstrate age appropriate visual working memory abilities. Their ability to recall words may be equal to that of their peers, but this is not true of their ability to recall multi-syllabic non-words. The ability to recall non-words is reliant on a multitude of variables such as the ability to encode and store novel words, word knowledge, vocabulary size, and the quality of phonological and lexical representations. Therefore, the use of the same tool (i.e. multisyllabic Non-word Recall) to examine verbal short-term memory can, and has, provided only limited insight into children with hearing impairment's verbal short-term memory abilities and their possible difficulties beyond the task itself.

It is unclear from the body of this research whether the subgroup of children with hearing impairment and additional language learning difficulties (LLD) exhibit the same but slower pattern of language and memory abilities as other orally educated children with hearing impairment who received their hearing aids or cochlear implant prior to the age of 2;6, or is their development qualitatively different? The research findings in the literature have highlighted that the majority of children with hearing impairment overcome initial delays in vocabulary and spoken language development by the time they reach school age. For the purposes of this study, children with LLD display delays in both receptive and expressive vocabulary and language above and beyond the initial delays that many children with hearing impairment display. However, it is unclear how extensive their difficulties are and how these deficits manifest themselves over time. It is also undecided from the literature what the strengths and weakness in memory abilities are for children with hearing impairment and LLD. In this context, the use of different memory assessments or a battery of memory assessments may provide the necessary additional information that will allow for a greater understanding of these children's visual and verbal short-term memory and working memory abilities. Therefore, the overarching research question being addressed by the current study is "What is the developmental profile and trajectory in vocabulary, language and memory for children with hearing impairment who exhibit language learning difficulties?" This broad research-derived question will be broken down into an aim and objectives in the next chapter.

CHAPTER 4 Methodology

4.1 Introduction

This chapter initially discusses the research aim and objectives for the study. It then examines the research philosophy pertinent to the study and its relationship to the research design and the methods of data generation. This chapter also discusses the research design, the methodological considerations and the rationale for this design. The second part of the chapter explains the recruitment procedures, inclusion and exclusion criteria, participants and their demographic characteristics and ethical issues. The third section of this chapter describes the standardized vocabulary, language and memory assessments utilized in the current study. This final part of this chapter discusses the development of an informal memory assessment and the rationale for its use in this study.

4.1.1 The aim and objectives of the research

The current research grew from the observation that some children with hearing impairment do not develop language as well as their hearing-impaired peers, despite optimum aiding and educational and therapeutic intervention. The research question emerging from the review of the literature is:

“What is the developmental profile and trajectory in vocabulary, language and memory for children with hearing impairment who exhibit language learning difficulties?”

The aim of the current research is to investigate factors associated with vocabulary and language development in this cohort of children.

As noted in chapters 2 and 3, literature on vocabulary and language learning and development in children with hearing impairment considers the age of identification of the hearing loss, the age and quality of aiding (thus ‘hearing age’), the impact of an oral educational and parental input. The specific objectives of the study therefore are as follows:

1. To profile memory, vocabulary and language development within a longitudinal study
2. To investigate what aspects of vocabulary, language and memory are impacting upon the development of these children
3. To develop a research and theory-driven intervention to pilot test the findings of the study

By addressing these objectives, it is anticipated that an evidence driven theory could be presented to explain the language difficulties being experienced and an initial intervention approach could be designed which may be valuable to other children who present with similar profiles.

4.2 An approach to research

The study of knowledge (i.e. epistemology) occurs within the wider context of a world view. Creswell (2014) identifies three components: philosophical world view, the design and the research method that are involved in an approach to research.

the philosophical world view: This can be defined as "the general philosophical orientation about the world and the nature of research that a researcher brings to the study" (p.6). According to Creswell (2014), the four commonly recognized world views are post-positivism, constructivism, transformative and pragmatism.

the design: "Research designs are the types of inquiry within the quantitative, qualitative and mixed methods approaches that provide specific direction for procedures in a research design" (p.12). Some examples of designs include, experimental designs, case studies, ethnographies and narrative research.

the research method: This is "the specific research method that informs the data collection, analysis, and interpretation that researchers propose for their studies" (p.15). These methods include quantitative, qualitative and mixed methods approaches.

4.2.1 Research Philosophy

The integration of practice and research is, I believe, fundamental to developing a greater theoretical understanding and evidence based practice. This process involves evaluating the ways in which populations, in this case children with hearing impairment, are examined and asking questions as to why researchers cannot try to investigate assumptions differently. It also includes challenging the typical tools that have been utilized to collect data and exploring new assessments and the possible information that can be gained from them. This allows for the possibility of new interpretations and insights to materialize which may possibly be utilized to develop further more appropriate clinical practice. These beliefs, alongside my extensive clinical experiences, influenced the development of the research questions, as well as the design of the study itself. This study is set within a post-positivist paradigm. This worldview asks questions of the world and does this through the use of experimental measures and observations, such as assessments which will test theories or assumptions. Post-positivists believe that "theories govern the world, and these theories need to be tested or verified and refined so that we can understand the world" (Creswell, 2014, p.7). This paradigm frequently employs a quantitative approach, which allows for an evaluation of these theories.

4.3 Methodological considerations

Typically research in the field of paediatric hearing impairment has followed three paths: individual case reports examining complex or unusual cases; cohort or case series studies; and large scale cross-sectional studies, whereby children with hearing impairment are compared with normally hearing peers. There is vast heterogeneity among children with hearing impairment due to differences in age of identification, aetiologies of deafness, degree of hearing loss, language modality/communication mode, educational environment, parental input and the possible presence of additional disabilities. Young and Temple (2014) and Marschark et al. (2015) support this assertion, as well as identifying other factors for children with hearing impairment, which must also be acknowledged. These include environmental influences including differing abilities of communicators either using spoken or signed languages, parental education and social environments. Young and Temple (2014) state that this heterogeneity "raises important questions for researchers about how to define or construct what might be a representative sample. However, what might be meant by a representative sample is itself differently defined depending upon the epistemological and methodological basis of the study designs" (p.88). The follow sections discuss the decision-making with reference to the design of the current study, the research method and data collection.

4.3.1 Research designs and methods in the field of paediatric hearing impairment

The early research in the field of paediatric cochlear implantation focused on evaluating the effectiveness of cochlear implants in children with hearing impairment by using speech perception testing alongside the assessment of receptive vocabulary abilities at six month intervals during the child's first two to three years of cochlear implant use (Fryauf-Bertschy et al., 1992; Miyamoto et al., 1997; Osberger et al., 1991; Tyler et al., 1997; Waltzman et al., 1994). This research did not differentiate between the children with hearing impairment who utilised different communication modes (i.e. speech, sign or total communication) (as identified in Chapter 2, Table 2.1 and 2.3). It is well documented in the literature that there are considerable discrepancies in the spoken language outcomes in children with hearing impairment (See Sections 2.6 and 2.7). As a way in which to investigate the variability in language development in children with hearing impairment, many researchers have chosen retrospectively to evaluate spoken language outcomes (Boons et al., 2012; Geers et al., 2009; Geers and Nicholas, 2013; Nicholas and Geers, 2006). Other researchers have prospectively analysed data in order to identify patterns of strengths and weaknesses in the language development of children with hearing impairment (Hayes et al., 2009; Holt and Svirsky, 2008; Moeller et al., 2007b; Nicholas and Geers, 2013; Niparko et al., 2010; Sarant et al., 2009) (as identified in Table 2.2). Both of these research designs enabled the investigation of the language acquisition of a greater number of children with hearing impairment (Boons et al., 2012; Geers and Sedey, 2011) and provided an increased understanding of how these children develop.

Many of the recent longitudinal quantitative studies have examined the language development in young cochlear implant users, as a way in which to establish expectations of progress (Geers et al., 2009; Harris et al., 2013; Nicholas and Geers, 2013; Niparko et al., 2010; Pisoni et al., 2011). These studies did not make use of matched controls, as they are not comparing different groups of children with hearing impairment, but identifying developmental patterns within a certain population of children with hearing impairment. These studies set clear inclusion criteria, which may typical of the characteristics of many children with hearing impairment. The criteria frequently include a specific age under which their device was fitted, speech as their primary mode of communication and no additional known disabilities. Both types of large-scale studies (retrospective and prospective) and case series use these inclusion criteria, which has enabled comparison of children with hearing impairment with other studies using the same criteria and comparable assessment batteries. Researchers have also differentiated their participant groups based upon degree of hearing loss, communication mode or hearing devices. This process has supported researchers in gaining a greater understanding of the differences in the rate of vocabulary and language acquisition of different populations of children with hearing impairment (Fitzpatrick et al., 2011; Lederberg and Spencer, 2009; Moeller, 2000; Spencer, 2004; Stiles et al., 2012; Tomblin et al., 2015; Yoshinaga-Itano, 2003; Yoshinaga-Itano, 2006; Yoshinaga-Itano et al., 2010).

In contrast to large-scale studies, Chilosi et al. (2013) utilised a case series design, which enabled them to examine comprehensively the changes in each individual child's language development during their preschool years (See Section 4.5 for a discussion of the use of a case study and case series). They longitudinally investigated the language and vocabulary development of six Italian children with hearing impairment who were recruited to the study between the ages of between 16 and 24 months. This study and other large quantitative studies found that a significant proportion of children with hearing impairment do not achieve age appropriate language, even if fitted with their hearing aids or cochlear implant by the age of 2;0 years (See Chapter 2, Sections 2.6 & 2.7). However, many of these studies did not provided the specific language and vocabulary outcomes for those children who did not succeed in developing age appropriate language abilities. The matching of individual participants has been a further way in which to examine differences in areas of development between children with hearing impairment. There are inherent difficulties with this design. As for one example, Hawker et al. (2008) matched six children with cochlear implants who appeared to be following a typical developmental trajectory with six others who were exhibiting language impairment. This study was unable to match the children identically according to aetiology, duration of cochlear implant/hearing aid use, chronological age and communication mode. The heterogeneous nature of the population of children with hearing impairment makes it methodologically difficult to match individual children, as there are many possible variables interacting with their language development. It is also an issue that until we know which variables are influential, we do not know on which variables we need to match and which can be ignored.

In summary, the outcomes from large-scale quantitative studies have made it possible for patterns of spoken language development and expectations of progress to be identified in children with cochlear implants. These quantitative studies have supported both clinicians and researchers in developing an evidence base regarding expectations of language development in orally educated children with hearing impairment. However, it is acknowledged that large quantitative studies yield results that may be more robust, but may mask important individual differences that could warrant further investigation (Creswell, 2014; Yin, 2009).

4.3.2 Data collection and analysis

The decision making process involved in collecting the data for the current study was multifaceted. In trying to address the research questions, decisions needed to be made with regard to the ways in which to collect the data and what standardized instruments, if any, should be utilized by the researcher. As one of the primary aims of the study was to investigate the language development of a subgroup of children with hearing impairment, it was imperative that their abilities could be compared with other children with hearing impairment. Therefore, the vocabulary and language assessments chosen were ones that many other researchers had employed in their investigation of children with hearing impairment (See Chapter 2, Section 2.4.1 and Table 2.1)

This primary goal of the design and methodology of the current study was to address the research aims of the study whilst also taking into to consideration practical constraints and the possible effect upon the research design and data collection. As a result, the research design and methodology became an exercise in balancing the following factors. Figure 4.1 is a useful way in which to pictorially represent the process from which the methodology and study design developed.

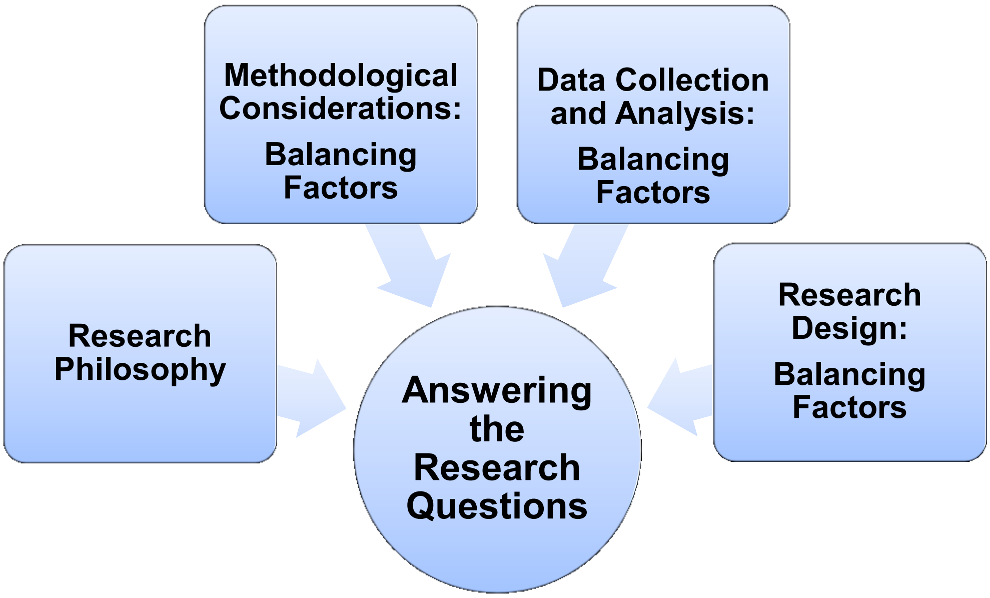

Figure 4.1 **The Balancing of Factors in Answering Research Questions**

These variables include the following practicalities:

1. Assessment considerations- Firstly, assessments need to be fit for purpose; that is to say that they test what they are supposed to be testing. Secondly, parents and support teams need to be able to understand the assessments, their purpose and the information they provide regarding the child's abilities.

2. Testing session- The administration of the assessments required three sessions over a two-week period. This meant that the timing of testing sessions needed to be co-ordinated carefully with gatekeepers and teaching staff to ensure that there was minimal disruption to the child's school day.

3. *Time demands*- The longitudinal nature of the study was essential to allow the researcher to identify changes in individuals over time as the children age (Breakwell et al. Hammond and Fife-Schaw, 2000). However, the practical implications meant that the same children needed to be accessible for data collection (e.g. administration of assessments) at three time points at 12 month

intervals. It also meant that the same individual needed to administer the assessments in order to increase internal validity.

4. Participant numbers- The numbers of children with permanent childhood hearing impairment are relatively small, and therefore accessing children who met the inclusion criteria made the participant numbers a smaller group still. The time demands of the assessment process and the longitudinal nature of the study were a consideration when deciding upon the number of children to be focused upon in this study.

5. Assessment administration- The researcher was the only person administering the assessments. In part, this was necessary due to time limitations as well as financial constraints mentioned above, but also due to the specialist nature of the field of paediatric hearing impairment. That is to say that the availability of other speech and language therapists who have extensive experience working with children with hearing impairment is very limited. The likelihood of experienced speech and language therapy professionals committing to annual data collection on three occasions is also limited. The potential for researcher bias is acknowledged, but this situation was unavoidable given the factors mentioned above. However, the benefit of the same person administering the assessments over the duration of the study is that the children were relaxed and familiar with the researcher, and therefore any anxiety that the children may have felt was minimised. The latter factors will be revisited in a consideration of the limitations of this research in Chapter 6, Section 6.8 and Chapter 8, Section 8.3.2.

4.4 Design of the study

A longitudinal case series design was used to gather quantitative data in order to address the research aims presented. The study sought to examine the vocabulary, language and memory abilities of a subgroup of children with hearing impairment who continue to exhibit substantial delays in their language development even after several years of hearing aid or cochlear implant use. Possible answers as to why some children with hearing impairment succeed and others struggle have been generated from the investigation of cognitive processes such as verbal short-term memory, working memory and verbal rehearsal speed

(See Chapter 3, Sections 3.6 and 3.7). However, the studies reported in Chapter 3 made use of similar tests and testing procedures as one another and very few studies used multiple tests to evaluate the functioning of verbal or visual short-term memory and working memory (See Chapter 3, Section 3.6). None of the recent research studies have made use of the memory assessments utilized in the current study or developed profiles of memory abilities in children with hearing impairment, as Alloway et al. (2009b) have done with children with other developmental disorders (See Chapter 3, Table 3.2). Further discussion of these memory tests and the ones utilized in the current study are elaborated upon in Section 4.11 in this chapter. It was hoped that the answers gained from this study would give professionals' greater insight and understanding into these children's strengths and weaknesses in spoken language, verbal and visual memory. This information could then lead to the development of more target specific interventions that could possibly address these difficulties at much younger ages.

4.5 Rationale for the study design

The current study aimed to investigate in detail the development and possible changes within individual children with hearing impairment who exhibited additional language learning difficulties. There has been little research to date that has specifically explored the language abilities of children with hearing impairment who continue to display significant deficits in spoken language development even after several years of intensive support and exposure to spoken language input and therefore this is a legitimate and topical area for study. The current study made use of a case series design which enabled an examination of the children's history of early spoken language learning and a more in-depth investigation into the children's linguistic and memory abilities individually and as a group.

The use of a case study is justified in specific situations "where the case represents (a) a critical test of existing theory (b) an area or unique circumstances (c) or a representative or typical case, or where the case serves a (d) revelatory or longitudinal purpose" (Yin, 2009, p.52). A case series is a descriptive analysis of a cohort of adults or children who exhibit the same or similar characteristics and undergo the equivalent clinical process of assessment, intervention or both (Creswell, 2014). A case series uses more than one case in order to provide stronger evidence and is reliant upon well-defined objectives and clear procedures and protocols to produce valid outcomes. The participants must be selected according to the inclusion/exclusion criteria and the study design must be prospective in nature. Case study designs explore individual or small group characteristics in greater depth and detail, but may be less generalizable than larger cohort studies (Yin, 2009; Yin, 2012). The validity of the data is increased if multiple sources of evidence are gathered in the case series (Yin, 2009). Given the heterogeneous nature of children with hearing impairment and specifically this group of children with additional language learning difficulties, unique characteristics of this group are better identified utilizing a case series design. A case series design could provide possible answers and/or identify clinical indicators that may allow for early identification of difficulties. The different amplification devices used by participants, their wide age range and their different educational environments were specifically chosen in the current study, as these variables are characteristic of many children with hearing impairment.

In summary, comprehensive vocabulary, language and memory assessment data collection occurred annually at three time points in order to inform an analysis of progress over time in this population of children with hearing impairment and LLD. It is generally accepted that memory abilities continue to develop and change into adolescence (Baddeley, 2003; Gathercole et al., 2004). Therefore, the longitudinal nature of the current study is additionally valuable in that it allows for the re-examination of children's memory abilities and the possible identification of memory profiles that have gone unnoticed. The results from this study may create an increased understanding of this group of children with hearing impairment and additional language learning difficulties and provide a way forward with regard to their clinical management.

4.6 Ethical approval

Ethical approval for this study was obtained from the author's University Ethics Committee, a local National Health Service (NHS) Research Ethics Committee and National Health Service Research & Development Department, reference number 09/H1008/109 (See Appendix 1F and 1G for Ethical Approval letters from both the University and NHS Research Ethics Committee). An amendment was submitted to NHS Ethics and approved for the therapeutic study (See Appendix 1H).

4.7 Method

4.7.1 Inclusion criteria

Children were eligible for inclusion in the longitudinal, assessment phase of the study if they met the following criteria:

- Spoken language is their primary mode of communication (i.e. oral)
- English is the language used in the home environment
- Parents use spoken language as their primary mode of communication
- Child is a consistent hearing aid/cochlear implant user
- Fitted with their hearing aid/cochlear implant prior to the age of 2;6
- Considerable language learning difficulties as identified by their teacher of the hearing-impaired, which can be defined as functioning more than 1 standard deviation below the mean on standardized assessments of both receptive and expressive vocabulary and spoken language
- Nonverbal cognitive abilities greater than a standard score of 85, as assessed by an Educational Psychologist

As part of the process for allocating educational support to children with hearing impairment, an Educational Psychologist must assess their learning needs and provide a report regarding the type and amount educational support that is required. Seven participants were invited to take part, but on assessment, one child was found to have receptive vocabulary and language abilities within normal limits, but mildly delayed expressive language difficulties. Therefore, he did not meet the inclusion criteria and did not take part in the study.

4.7.2 Recruitment and sampling

The participants were recruited via opportunity sampling from educational authorities in the North of England where children with hearing impairment are educated either in a mainstream school or in a specialist school for children with hearing impairment. The Educational Inclusion Services for children with hearing impairment were contacted and provided with the Study Information Sheet regarding the current study (See Appendix 1A). This information was disseminated to specialist teachers of children with hearing impairment who acted as gatekeepers by identifying possible children with hearing impairment who exhibited language learning difficulties. The teachers distributed Parent Information letters (See Appendix 1B). Parents contacted the researcher by phone, indicating that they were interested in having their child participate in the study. The researcher discussed the study in detail and provided parents with a consent form, which was signed and returned to either the school or directly to the researcher by post. Written parental consent was obtained for each child, as well as assent from all participants. (See Appendix 1D for the Consent form).

4.8 Participants

The participants were six children/adolescents with congenital, bilateral, moderate to profound sensorineural hearing impairment. The clinical experience of the researcher found that these children's characteristics (i.e. their educational placement, consistency of device use, communication mode and age of hearing aid or cochlear implant fitting) are similar to many children with hearing impairment within England (Davis et al., 2011) (See Table 4.1 for Participant Characteristics). At the beginning of the study, participants were aged between 8;5 and 13;10 years. Three participants were educated in a mainstream school, while the other three participants attended a school for children with hearing impairment. The information provided in Table 4.1 and Appendix 2 (Audiological Information) is not comprehensive, but is accurate. All of the children had all been fitted with hearing aids or a cochlear implant by the age of 2;6. However, there was limited historical audiological information available for the participants regarding pre-implant hearing levels and audiological histories, as a result of the digitization of medical and educational records within the National Health Service and educational services. All of the audiological information was accessed either from speech and language therapy records and/or educational reports.

At the beginning of the study, all of the children exhibited standard scores, of more than 1 standard deviation below the mean on two or more assessments of receptive and expressive vocabulary and language. That is to say, that their standard scores on standardized tests such as the Expressive Vocabulary Test -2 (Williams, 2007) or subtests from assessments such as the Clinical Evaluation of Language Fundamentals Fourth Edition UK (Semel et al., 2006) were significantly delayed in relation to their normally hearing peers. The teachers of the hearing-impaired also highlighted that the children’s progress was markedly slower than they would have expected. Therefore, the term “language learning difficulties” was utilized to describe this specific population of children with hearing impairment (See Chapter 1, Section 1.4 and Chapter 2, Section 2.8 for a more detailed discussion of the use of this terminology). The children who attended mainstream settings received three to five visits per week from a teacher of the hearing-impaired or a specialist teaching assistant in hearing impairment, working to a programme of support set by the teacher of the hearing-impaired. A qualified teacher of the hearing-impaired and a teaching assistant taught the children attending a specialist school for children with hearing impairment. All six children received ongoing support from a speech and language therapist prior to and throughout the duration of the study.

Table 4.1 *Characteristics of the children*

Child	Gender	Type of hearing loss	Device	Age at first point of testing	Educational Environment at the beginning of the study	Access to Speech from 250Hz-4000Hz when aided/CI
A	male	Moderate to Severe loss	*HA	8;5	Mainstream	yes
B	female	Severe to profound loss	+CI	13;10	Mainstream	yes
C	male	Sloping Severe to profound loss	+CI	9;9	School for Children with HI	yes
D	male	Severe loss	*HA	10;3	School for Children with HI	yes
E	female	Severe loss (progressive)	*HA	9;11	Mainstream	yes
F	male	Severe/profound loss	+CI	9;4	School for Children with HI	yes

*HA= Hearing Aid User
+CI= Cochlear Implant User
HI= Hearing Impairment

4.9 Record keeping and security

All information regarding participants such as consent forms, video recordings and recording sheets was kept in a locked cabinet in the researcher's office. All recording sheets were anonymised and assigned Child A, B and so on. The computer the researcher utilised was password protected. The researcher informed parents that the information regarding their child would be kept anonymous and that they did have the right to withdraw at any time and thus data were linked to consent forms, but kept separate for all analytical purposes. With parental consent, the researcher did share outcomes of assessments with local speech and language therapy and education services. As per the consent form, all research data will be destroyed five years after the completion of the research study in line with University guidelines on the retention of research data.

4.10 Vocabulary and language assessments

Standardized vocabulary, language and memory assessments were administered annually to six children with hearing impairment (See Table 4.2 and 4.4). The assessments utilized needed to encompass a large age range, due to the participants' ages, as well as allowing for re-administration annually at three data collection points (for a discussion of assessments used with children with hearing impairment see Chapter 2, Section 2.4 and Table 2.1). The British Picture Vocabulary Scale 2, the Expressive Vocabulary Test-2 and subtests from the Clinical Evaluation of Language Fundamentals (CELF-4UK) Fourth Edition (Semel et al., 2006) were chosen. The test battery (see Table 4.2 below) in the current research study is very similar to that of Geers and Sedey (2011), Geers and Nicholas (2013) and Harris et al., (2013) in that it targets both receptive and expressive aspects of language that are at risk of poor development. Geers et al. (2009) found that different aspects of language develop at different rates in children with hearing impairment, and therefore it is important to compare different abilities within expressive and receptive language. The following discussion provides an overview of the assessments and subtests utilized in the current study.

Table 4.2 ***Vocabulary and language assessments***

Receptive Vocabulary	Expressive Vocabulary	*Receptive Language	*Expressive Language
+British Picture Vocabulary Scale 2	+Expressive Vocabulary Test-2	+Word Classes Receptive	+Word Classes Expressive
		Understanding Spoken Paragraphs	+Recalling Sentences
			+Formulated Sentences

*Subtests from Clinical Evaluation of Language Fundamentals-4 (CELF-4UK)

+Denotes 5 items incorrect discontinue rule, whereby the assessment is completed at that point

The Clinical Evaluation of Language Fundamentals (CELF-4 UK) Fourth Edition (Semel et al., 2006) is an assessment tool that is comprised of subtests that specific areas of receptive and expressive language, verbal short-term memory and working memory, as well as phonological awareness. Five subtests from the CELF-4UK (Semel et al., 2006) were chosen to be included on the current study. It was standardized on 2,259 children aged from 5;0 to16;11 years. The CELF-4 is widely used by both researchers and clinicians when investigating language development and disorder in typically hearing and children with hearing impairment (Dawson et al., 2002; Ebbels et al., 2012; Freed et al., 2012; Pisoni et al., 2011) (See Chapter 2, Section 2.4.1 and Table 2.1). The use of subtests from the CELF-4UK (Semel et al., 2006) allowed for a detailed investigation of both receptive and expressive language and insight into how the children's difficulties may manifest themselves in an educational setting. The results of these subtests used in conjunction with the British Picture Vocabulary Scale 2 (Dunn et al., 1997) and EVT-2 (Williams, 2007) provided a holistic evaluation and profile of the these children's language abilities and possible changes over time. Table 4.3 provides information regarding test-retest reliability coefficients from the instruction manuals for all vocabulary and language assessments. This information is useful in understanding that these tests and subtests are reliable standardized assessment tools in their own right.

Table 4.3 ***Test-retest reliability coefficients of vocabulary and language assessments***

Vocabulary and Language Assessments	Test-Retest Reliability
British Picture Vocabulary Scale 2	.91
Expressive Vocabulary Test-2	.95
CELF-4 Word Classes Receptive	.84
CELF-4 Word Classes Expressive	.83
CELF-4 Understanding Spoken Paragraphs	.73
CELF-4 Recalling Sentences	.92
CELF-4 Formulated Sentences	.83

(Test-retest reliability coefficients are from the assessment manuals)

4.10.1 Vocabulary

British Picture Vocabulary Scale 2

The British Picture Vocabulary Scale 2 (BPVS) (Dunn et al., 1997) and Peabody Picture Vocabulary Test-3 (PPVT) (Dunn and Dunn, 2007) which is the American equivalent, are widely used in research and clinical practice to evaluate receptive vocabulary in children with hearing impairment (El-Hakim et al., 2001; Fagan and Pisoni, 2010; Geers et al., 2009; Hansson et al., 2004; Harris et al., 2013; Hayes et al., 2009; Pisoni et al., 2011; Stiles et al., 2012). The BPVS 2 (Dunn et al., 1997) tests a child's ability to identify the correct picture from a set of four, when verbally presented with a target word. It contains more nouns and adjectives than verbs. This assessment was standardized on 3278 normally hearing children and young people aged from 3;0 to 16;11 years. A low score on this test would indicate delayed receptive vocabulary.

The Expressive Vocabulary Test-2

The Expressive Vocabulary Test-2 (EVT-2) (Williams, 2007) is often used in conjunction with the BPVS 2 (Dunn et al., 1997) to investigate if there is a discrepancy between the receptive and expressive vocabulary scores. This difference may indicate language delay or impairment. This test also highlights if the child has word finding difficulties. Previous researchers in both small and larger studies have utilized the EVT-2 as a way in which to test expressive vocabulary in children with developmental disabilities and language impairment (Archibald and Alloway, 2008; Archibald and Gathercole, 2006b; Geers et al., 2009). The EVT-2 is an American assessment that evaluates a child's ability to name a picture correctly or provide a word that is synonymous with the target word (e.g. a picture of a man is presented and the examiner asks "What is another name for *father*?" The child must say "dad" or "daddy"). In addition this test provides more information regarding verb, adjective and adverb knowledge than the BPVS 2 (Dunn et al., 1997). This assessment was standardized on 3,540 normally hearing children and adults from the age of 2;6 to 90+. A possible limitation of the EVT-2 is that it uses American vocabulary and clinicians must be aware of this when administering the assessment. This issue is addressed by the provision of examples of acceptable responses, which includes UK English variants.

4.10.2 Receptive language

Two subtests, Understanding Spoken Paragraphs and Words Classes, from the CELF-4UK (Semel et al., 2006) were used to assess receptive language.

Understanding Spoken Paragraphs

The Understanding Spoken Paragraphs subtest involves the examiner reading aloud a paragraph to the child, thus assessing comprehension through the child's ability to respond to three content-based questions and two that require the child to predict and infer information from the story. Three paragraphs are read aloud, with a total maximum score of fifteen.

Word Classes (Receptive)

The Word Classes (Receptive) subtest tests the ability to identify correctly two out of a possible four words that are related. These words are spoken to the child and may be repeated as many times as the child requires. The performance on this subtest provided insight into the child's semantic knowledge. (For example: **pillow**, tree, **bed,** shoe)

In addition, both subtests provided insight into classroom functioning, as classroom teachers expect children to demonstrate categorization abilities (e.g. "Tell me what things go together and why"), as well as comprehension of stories and the ability to answer questions related to the content.

4.10.3 Expressive language

Three subtests, Recalling Sentences, Formulating Sentences and Word Classes (Expressive), from the CELF-4UK (Semel et al., 2006) were utilised to assess expressive language. These subtests also require that the child comprehend the instructions, as well as the vocabulary within each task. These assessments were selected because they illuminate particular difficulties with memory, syntax, grammar and semantic abilities. These are areas of language development in which children with hearing impairment have been found to exhibit weakness or delays (Harris et al., 2013; Szagun, 2001; Szagun, 2004).

Recalling Sentences

The Recalling Sentences subtest requires the child to listen to sentences of increasing complexity and length and recall them verbatim. The sentences are scored individually, with a maximum score of three. The score is reduced to 2, 1 or 0 if there are errors. These may include substitution or omission of words, as well as confused word order. This test relies on short-term memory abilities, semantic and linguistic knowledge, and higher level language abilities. Sentence recall tasks also demonstrate the functioning of the episodic buffer, which integrates information from the phonological loop and long term memory (Alloway, 2007; Alloway and Gathercole, 2005). An inability to recall sentences correctly is considered a clinical indicator of language learning difficulties and working memory problems (Archibald and Joanisse, 2009; Freed et al., 2012).

Formulated Sentences

The Formulated Sentences subtest asks the child to use a key word in a sentence. The child must generate a sentence using that target word with reference to the picture. The sentence is awarded a maximum of three points based upon its content and grammatical correctness.

Word Class (Expressive)

The Word Classes (Expressive) subtest requires a child to listen to four key words and decide which two words are related. The child must then explain how they are associated with one another. The child continues this task until there are five incorrect answers.

4.11 Memory

The current study utilized standardized memory assessments from the Working Memory Test Battery for children (WMTB-C) (Pickering and Gathercole, 2001) and Automated Working Memory Assessment (AWMA) (Alloway et al., 2007) to evaluate verbal and visual short-term memory and working memory. The WMTB-C was standardized on 729 children aged between aged between 4;7 and 15;9 years.

Table 4.4 ***Memory assessments***

*Verbal Short-term Memory	*Verbal Working Memory	*Visual Short-term Memory	#Visual Working Memory
Digit Recall	Backward Digit Recall	Block Recall	Odd One Out
Word Recall	Listening Recall		
Non-word Recall			

*Subtests from the Working Memory Test Battery for Children (WMTB-C) (Pickering and Gathercole, 2001)

#A subtest from the Automated Working Memory Assessment (AWMA) (Alloway et al., 2007)
~ All Memory assessment have a discontinue rule 3 incorrect answers on a subtest and the examiner must stop

The test-retest reliability was assessed with a subgroup of children aged between 5;4 and 8;0 years (i.e. Years 1 and 2) and 9;6 and11;6 years (i.e. Years 5 and 6). The sample size of each year group was 25 with the exception of Year 6, which was 24 children, thus a total of 99 children. The interval time between testing was two weeks. The same stimuli were utilized in the AWMA, which is a computerized version of the WMTB-C. The AWMA was standardized on 1269 children aged between 4;8 and 21;6 years. The test-retest sample was randomly selected across the age range of the assessment (n=128). The test-retest coefficients, for some subtests, were greater than those of the WMTB-C. This may be due to the wider age range of the children involved in the reliability sample for the AWMA, as well as the use of a computer-based assessment, which maybe more engaging with young participants. The correlation coefficients appear in Table 4.5.

Table 4.5 ***Test-retest reliability coefficients for the WMTB-C and the AWMA***

Memory Assessments	WMTB-C Years 1/2 (ages 5-7 years)	WMTB-C Years 5/6 (ages 9-11 years)	AWMA
Digit Recall	.81	.82	.89
Word Recall	.80	.64	.88
Non-word Recall	.68	.43	.69
Backward Digit Recall	.53	.71	.86
Listening Recall	.83	.38	.84
Block Recall	.63	.43	.90
AWMA Odd One Out			.88

Standardization test-retest reliability coefficients provided by the assessment manuals
WMTB-C (Pickering and Gathercole, 2001) AWMA (Alloway et al., 2007)

Previous researchers have made use of AWMA and WMTB-C, as a way in which to investigate working memory deficits in children with specific language impairment and developmental co-ordination disorder (Alloway and Archibald, 2008; Alloway et al., 2009b; Archibald and Alloway, 2008; Archibald and Gathercole, 2006b). Alloway et al., (2009) made use of a battery of subtests from the AWMA in her exploration of verbal and visual memory abilities in children with developmental disorders. The use of multiple tests to evaluate memory may highlight possible patterns, which may be useful in further identifying and defining strengths and weaknesses in memory abilities (Harris et al., 2013). The use of more than one measure of verbal short-term memory and working memory may also allow for a greater understanding of strengths and weakness in tasks associated with different amounts of semantic knowledge and the retrieval of lexical representations from the long term memory.

The current study utilized three different subtests from the WMTB-C to test verbal short-term memory, two subtests from the WMTB-C to evaluate verbal working memory, one subtest from the WMTB-C to assess visual short-term memory and the Odd One Out subtest from the AWMA to evaluate visual working memory. This test provides computer-generated instructions for completing the assessment. The instructor provided clarification of the requirements of the task by repeating these instructions. The outcome of these subtests addressed the question as to whether there were generalized memory difficulties across both the visual and verbal domains.

4.11.1 Verbal short-term memory

A number of researchers in the field of developmental disorders and hearing impairment have investigated the link between verbal short-term memory difficulties and poor language outcomes. A weakness in verbal short-term memory indicates an impairment in the functioning of the phonological loop (Baddeley, 2003; Baddeley, 2012). There is a strong correlation between vocabulary development and verbal short-term memory abilities in typically hearing, language impaired and children with hearing impairment (Dillon et al., 2004; Gathercole et al., 1997b; Gathercole et al., 2005; Hansson et al., 2004; Willstedt-Svensson et al., 2004). Performance on the traditional multisyllabic non-word repetition task correlates highly with working memory, reading, and receptive vocabulary abilities in children with hearing impairment. Researchers have utilized non-word repetition tests and digit recall tasks, as a way in which to identify these weakness in children with hearing impairment (Dawson et al., 2002; Lina-Granade et al., 2010; Pisoni and Cleary, 2003; Willstedt-Svensson et al., 2004) (See Chapter 3, Section 3.7 and Table 3.2).

Digit Recall

The Digit Recall task from of the WMTB-C (Pickering and Gathercole, 2001) assesses the functioning of verbal short-term memory. In this task, children are asked to repeat a sequence of numbers in the correct order. These sequences increase by one digit from a starting point of two after four successful attempts until the child cannot correctly repeat four attempts at that sequence length.

Word and Non-word Recall

The Word Recall and Non-word Recall subtests from the WMTB-C (Pickering and Gathercole, 2001) also assess verbal short-term memory abilities. The Word Recall subtest asks children to recall correctly single syllable words that are consonant-vowel-consonant (CVC) in structure. The Non-word Recall subtest follows the same procedure and the items have the same CVC structure as the "real" words. There are no repetitions allowed in either of the subtests. The tasks increase in complexity, as children are required to recall four targets correctly in each subgroup of either two, three or four words. The subtest ceases when the child cannot correctly imitate four targets within a subgroup. The Non-word Recall task on the WMTB-C addresses the possible confounding variable of oro-motor weakness and phonological difficulties, as the non-word task asks children to repeat single syllable, CVC nonsense words, instead of multisyllabic nonsense words such as those in traditional verbal short-term memory assessments (See Chapter 3, Section 3.4.1).

4.11.2 Verbal working memory

The two verbal working memory measures were also from the WMTB-C (Pickering and Gathercole, 2001). These tests evaluate a child's ability to remember verbal information whilst simultaneously processing and manipulating it. Success at these tasks involves the functioning of the central executive (Baddeley, 2003;

2012). The two subtests used were the Listening Recall and Backward Digit Recall task.

Listening Recall

This task asks a child to listen to a sentence and state if it is true or false, then state the final word of the sentence. For instance, “Pineapples have legs.” The child must state “False Legs.” This method continues for two sentence sequences whereby the child must state whether the two statements are true and false and also recall the final word in both of the sentences in the correct order. This procedure continues for six attempts. If the child is successful four times, then the number of sentences increases to three and so on.

Backward Digit Recall

In this task, the child must recall spoken digits in the reverse order. The digits are presented at one per second. The process begins with two digits and the child must complete this task correctly on four occasions. The assessment then moves on to three digits to be recalled in the reverse order and so on.

4.11.3 Visual short-term memory

The Block Recall task from the WMTB-C (Pickering and Gathercole, 2001) evaluates the functioning of the visuo-spatial sketch pad (Baddeley, 2012). The assessment tests a child’s ability to recall visually the order in which blocks are tapped by the examiner. The child must correctly tap the blocks in the same order as was observed. This task must be successfully completed four times before moving on to a longer sequence of blocks.

4.11.4 Visual working memory

The Odd One Out subtest is a visuo-spatial working memory subtest from the AWMA (Alloway et al., 2007). It assesses the functioning of the visuo-spatial sketch pad and the central executive. It is appropriate for use with individuals aged from 4;6 years to 21;6 years. This subtest asks the child to recall the “odd one out” of a group of three shapes presented horizontally on the screen. The visual working memory task specifically evaluated visual spatial working memory using shapes without an identifiable name, which meant that the task did not rely upon phonological encoding in order for it to be completed. The child identifies the shape that does not match the other two by pointing to it. At the end of each presentation of shapes, the screen becomes blank. The child must identify the location of the “odd” shapes in the correct order. The participant must complete this task four times to move onto the next subgroup. Again this task increases in difficulty, as children need to recall more shapes in the correct order (2, 3, 4, 5) if they are successful at a previous level.

4.12 Informal Memory Assessment

4.12.1 Theoretical rationale for the Informal Memory Test

The Informal Memory Test was devised in order to compare the memory and processing abilities (i.e. working memory) of the children using the same words presented either visually or verbally. This type of assessment is not currently available in the form of a standardized test, and therefore a task that would allow for the evaluation and comparison of verbal and visual working memory was developed. This informal assessment made use of tasks from the research of Montgomery (2000a, 2000b, 2008) in his investigation of real time processing in children with specific language impairment and typically developing children (Montgomery, 2000a; Montgomery, 2000b; Montgomery, 2008). His research utilized three different memory tasks, which increased in complexity. In the first instance, the children were required to listen to words and recall as many of them as possible in any order. The second condition asked the children to recall four words that they had listened to in order, according to physical size of the object. The third task required them to listen to five words and reorganize them into two semantic categories, as well as arranging them in order from the smallest object to the biggest. For example: ‘bike, flower, car, tree, plane.’ The task would require the child to recall the words in the following order: ‘bike, car, plane’ and then ‘flower, tree.’

The test in the current project was an amalgamation of Montgomery’s (2008) tasks, with an additional element, which addressed visual working memory. The initial task required the children to recall five nouns from the same semantic category and order them from smallest to biggest according to size of the object

(See Appendix 11 for the pictures and words used during this assessment). For example: “apple, strawberry, orange, grape, pineapple.” The correct response would be “grape, strawberry, apple, orange, pineapple.” This task was performed with five semantic categories: body parts, clothes, animals, transportation, and household items. After the child completed the five groups from the listening task, he/she was asked to name five individual pictures from the same semantic category when they were placed in front of him/her in a random order. The pictures were then removed and the child was required to recall the pictures, but in the correct order from smallest to biggest. This process continued for the same five semantic categories as the verbal task. The maximum score for each semantic category was 5. To achieve this score the child must recall all five words in the correct order from smallest to largest. The total maximum score for each task (verbal or visual) was 25.

4.12.2 Recruitment and consent from parents for the Informal Memory Test

Parents of typically developing children ages 7;0 to 10;2 at a large primary school were informed of the research project and sent information, as well as Opt Out consent forms (See Appendix 1E). Parents were assured that if their child wished not to take part in the “memory games,” then their child would return to class. Their child’s participation was entirely voluntary and confidential. Only one parent asked that their child not be involved in the research study.

4.12.3 Informal Memory Test

The Informal Memory Test was administered to forty primary school children aged from seven to ten years old. There were ten children in each of the four year groups. The class teacher chose five boys and five girls to participate in the study. The teacher was asked to choose those children where English was their first language and there were no identifiable additional learning needs. This allowed for minimal disruption in the classroom, as well as a sufficient sample size from each year group to evaluate differences in the verbal and visual task.

4.12.4 Findings from the typically developing children on the Informal Memory Test

Descriptive statistics, using standard scores, were used to analyse data in conjunction with SPSS 19 (See Appendix 10). Group differences were examined using t-tests and correlations from the sample of children. Order of presentation: visual versus verbal, yielded no significant difference in scores (See Appendix 10, Table C). The tasks were correlated at .732, ($p<.0.01$) using Pearson Product Moment Correlation Coefficient (See Appendix 10, Tables A and B for correlations). The results demonstrated that the normally hearing children (*N*= 40) did equally well on the verbal task (i.e. recalling names of objects) as the visual task (recalling objects after naming the pictures). The assessment was sensitive to progression with age as older children performed better than younger children (See Appendix 10, Table F). This test was then incorporated into the assessment battery for the six research participants with hearing impairment.

4.13 Procedure

The same battery of standardized vocabulary, language and memory assessments was used, and administered annually, with each of the six children with hearing impairment throughout the study (see Table 4.2 and 4.4); providing three data points. All the children involved in the study were assessed in quiet settings within their own schools by the researcher. The children attended three, 40 minute sessions over the course of a two week period. The assessments were administered in the same order for every child in each of the sessions (See Appendix 12 for the order of assessments). The language and memory assessments chosen for the current study allowed for in-depth investigation into these areas of receptive and expressive language functioning, whilst also enabling a comparison of the participants with their peers with hearing impairment and the normative sample from each of the assessments (See Chapter 2, Section 2.4 for a discussion of the use of different assessments). After each assessment point, the researcher initiated a discussion of the assessment results with the children's parents by phone or e-mail. The children's teacher of the hearing-impaired and speech and language therapist were also provided with the assessment results annually. These results were then included in the child's annual educational report and discussed at their educational review meeting. The parents were also provided with a written summary of the research study's findings.

As the children's primary mode of communication was speech, sign language was not used during the administration of any of the assessments. As the children are hearing-impaired, lip-read information may be of additional help to them in understanding instructions or target words and sentences. Therefore, lip-reading was permitted during the administration of all assessments, with the exception of the verbal short-term memory assessments (See Table 4.4). This additional visual information may have invalidated the findings with this population of children, as the standardization information from the memory assessment stated that visual information should not be provided by the examiner. That is to say, that any additional visual information from the lip-reading of target sounds and words may have provided supplementary information and increased their scores, thus making it difficult to compare their results with their normally hearing peers.

4.14 Analysis

Descriptive statistics, using standard scores, were used to analyse data in conjunction with SPSS 19. Group differences were examined using mean differences, correlations, t-tests and Analysis of Variance from the normative sample from each of the standardized assessments. These analyses examined the change in memory and language profiles over time for the children with hearing impairment and LLD and allowed for a comparison of performance on different assessments.

4.15 Summary

The current research study utilized a case series design in order to assess the vocabulary, language and memory abilities of six children with hearing impairment who had additional language learning difficulties. The assessment battery investigated different aspects of receptive and expressive language and memory abilities in this cohort of children with hearing impairment, as different parts develop at different rates (Geers et al., 2009). The use of multiple measures of verbal and visual short-term memory and working memory as part of the memory assessment battery was designed to enable the development of robust profiles of memory abilities. The longitudinal nature of the study facilitated the in-depth analysis of the children's abilities, any changes over time, as well as the development of profiles, both individually and across the group as a whole. The development and use of the Informal Memory Test examined the relationship between visual and verbal working memory in the children with hearing impairment in comparison to normally hearing children with comparable language levels, aged between seven and ten years old.

CHAPTER 5 Results

5.1 Introduction

As noted in chapter 4 above, the aim of the research was to investigate factors associated with vocabulary and language development in a cohort of children with hearing impairment and LLD. Chapter 5 begins with the findings relating to the first two research objective designed to address this aim. These findings describe the vocabulary, language and memory results for each of the six participants and summarize their development over the course of the study. The second part of this chapter will focus on the strengths and weaknesses in vocabulary, language and memory abilities of the children as a group.

5.2 Research objectives 1 and 2

Research objective 1

To profile memory, vocabulary and language development within a longitudinal study

Research objective 2

To investigate what aspects of vocabulary, language and memory are impacting upon the development of these children

5.2.1 Pen portraits of participants and assessments

For specific information on each of the participant's characteristics, refer to Chapter 4, Section 4.8 and Table 4.1 and for detailed audiological information see Appendix 2. The assessment results are interpreted in the following manner. For the following tests, any standard scores less than 85 are more than 1 standard deviation below the mean and scores less than 70 are 2 standard deviations below the mean: British Picture Vocabulary Scale 2 (BPVS 2), Expressive Vocabulary Test-2 (EVT-2), Working Memory Test Battery for Children (WMTB-C) and Automated Working Memory Assessment (AWMA). For the subtests from the Clinical Evaluation of Language Fundamentals–4UK (CELF- 4UK), any standard scores less than 7 indicates that the scores are more than 1 standard deviation below the mean. The raw scores for each of the assessments are also included in the profiles for each of the children in the sections below. The scoring system for the Informal Memory Test is a maximum raw score of 25 for each of the verbal and visual parts of the assessment. The memory profiles for each child are divided between assessments, which focus on verbal short-term memory, verbal working memory, visual short-term memory and visual working memory.

Child A:

Background from case notes

This boy was the youngest participant in the study, entering the study at the age of 8;5. His language and memory abilities were assessed at ages 8;5, 9;5 and 10;5. He had a sloping bilateral hearing loss and wore digital hearing aids. His hearing loss ranged from mild to moderate in the low frequencies and a severe loss in the high frequencies. Child A was educated in a mainstream primary school and received support from the local services for children with hearing impairment and speech and language therapy. As a toddler, Child A had a history of difficulties learning new words. In practice, this meant that he did not seem to remember new vocabulary that was focused upon daily. The case notes from his teacher of the hearing-impaired stated that Child A would sometimes be able to identify a target word within a session (e.g. animal sound, everyday object) or even repeat it, but the words were not retained, and he could not use it or comprehend it the next day. Therefore, in order for Child A to learn words, the teacher of the hearing-impaired needed to review vocabulary on a daily basis and reinforce target words in a variety of settings. Currently, Child A continues to require this intensity of input, as he still exhibits difficulties in learning and retaining new vocabulary.

Table 5.1 ***Child A's annual vocabulary and language assessment results using standard scores***

Assessment	Year 1	Year 2	Year 3
~British Picture Vocabulary Scale 2	66	71	55
^Expressive Vocabulary Test-2	70	71	74
¥*Word Classes Receptive	7	5	8
¥*Understanding Paragraphs	6	8	6
¥+Word Classes Expressive	6	5	8
¥+Recalling Sentences	3	3	3
¥+Formulated Sentences	2	2	2

~ Receptive Vocabulary ^ Expressive Vocabulary ¥ Denotes CELF-4 subtests

* Receptive Language + Expressive Language

Vocabulary and Language

Child A demonstrated better standard scores in expressive vocabulary than receptive. His expressive vocabulary improved over the duration of the study, but remained outside the age appropriate range (See Table 5.1). By the completion of the study, Child A's scores on the Word Classes Receptive and Expressive subtests had improved to a standard score of 8, which is within normal limits (CELF-4 UK) (Semel et al., 2006). His expressive language remained considerably delayed, as he displayed standard scores of 2 on the Recalling Sentences and 3 on the Formulated Sentences subtests of the CELF-4UK (Semel et al., 2006). However, his raw scores on the EVT-2 (expressive vocabulary) and both the Recalling Sentences and Formulating Sentences (expressive language) from the CELF-4UK improved over the duration of the study. This is in comparison with the receptive vocabulary and language assessments whereby there was only a small improvement in his raw scores (See Table 5.2). Table 5.1 provides a summary of his assessment results over the duration of the period of the study. A comparison of his receptive and expressive vocabulary and language results using standard scores appear below in Figures 5.1, 5.2 and 5.3.

Table 5.2 ***Child A's annual vocabulary, language and memory assessment results using raw scores***

Assessments	Year 1	Year 2	Year 3
Memory Assessments			
Non-word Recall	13	18	17
Word Recall	15	15	13
Digit Recall	24	25	26
Listening Recall	6	6	6
Backward Digit Recall	12	14	12
Block Recall	21	23	23
Odd One Out/AWMA	17	19	27
Vocabulary Assessments			
EVT-2	61	71	80
BPVS 2	45	47	49
Language Assessments			
Receptive			
Word Classes (Receptive)	3	4	10
Understanding Paragraphs	7	8	7
Expressive			
Word Classes (Expressive)	5	3	8
Recalling Sentences	29	32	35
Formulated Sentences	21	23	25

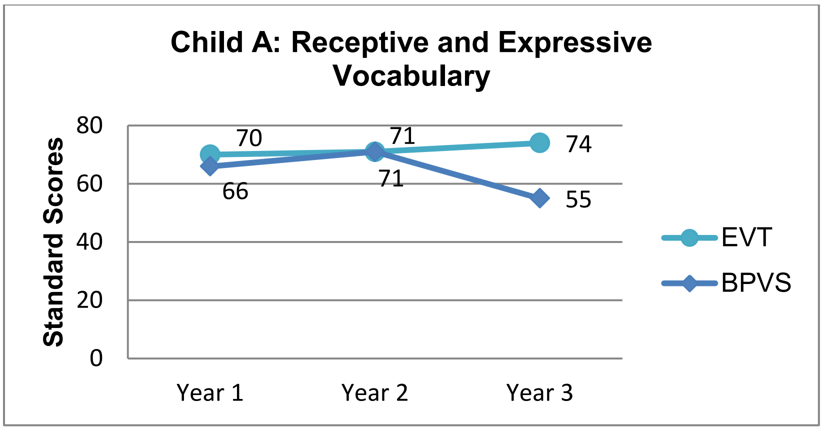

Figure 5.1 **Expressive Vocabulary Test-2 (EVT) and British Picture Vocabulary Scale 2 (BPVS) Standard Scores**

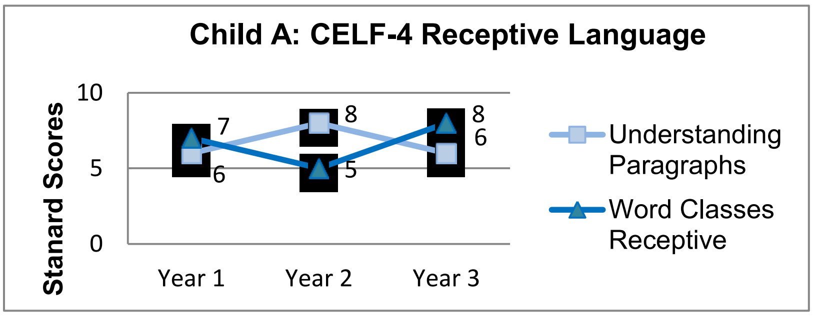

Figure 5.2 CELF-4UK Receptive Language Standard Scores

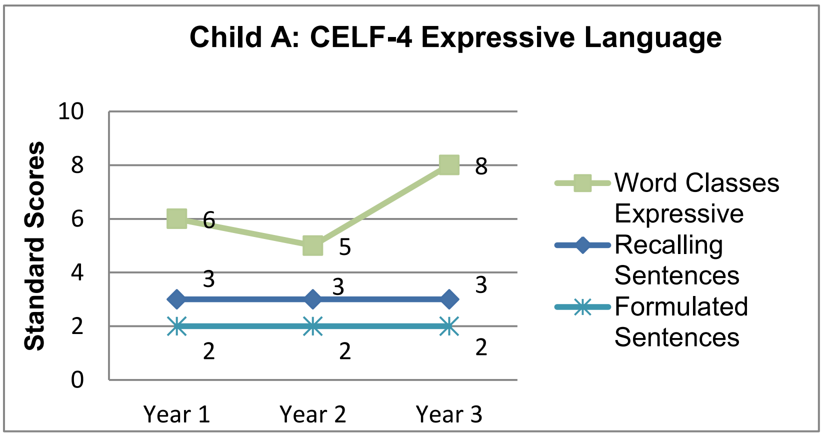

Figure 5.3 **CELF-4UK Expressive Language Standard Scores**

Memory

Throughout the study, Child A displayed a weakness in his ability to recall words, but age appropriate skills in Non-word and Digit Recall (See Table 5.3). He also exhibited strengths in Backward Digit Recall and age appropriate ability in visual short-term memory and working memory. However, his raw scores showed only minimal improvement over the course of the study, with the exception of the Odd One Out task. With regard to the Listening Recall task, Child A found it difficult to comprehend and follow the instructions for this test, which may have had a negative impact upon his performance. His raw scores of 6 remained unchanged throughout the study (See Table 5.2). Over the course of the study, Child A consistently performed better on the visual task than the verbal task on the Informal Memory assessment. A comparison of verbal and visual short-term memory and working memory tests are in Table 5.3 and Figures 5.4, 5.5, 5.6 and 5.7.

Table 5.3 ***Child A's annual memory assessment results using standard scores***

Assessment	Year 1	Year 2	Year 3
±Non-word Recall	104	124	117
±Word Recall	81	78	71
±Digit Recall	89	89	92
∞Backward Digit Recall	100	103	93
∞Listening Recall	76	76	68
+ Block Recall	85	90	81
# Odd One Out	107	103	123
***Informal Memory Test Visual Score**	19	19	20
***Informal Memory Test Verbal Score**	15	15	15

±Verbal Short-term Memory ∞Verbal Working Memory * Denotes Raw scores

+Visual Short-term Memory #Visual Working Memory

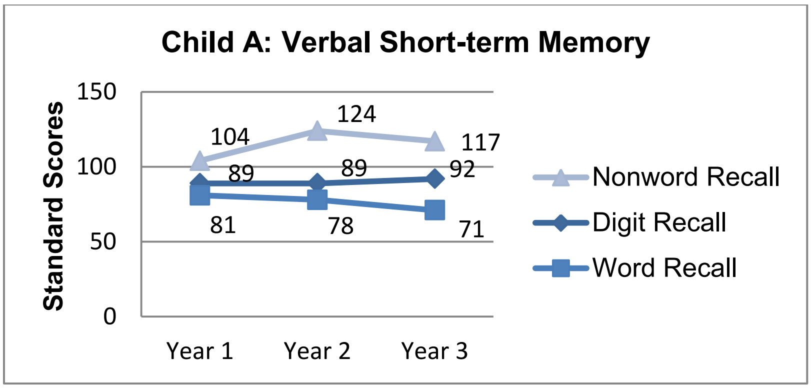

Figure 5.4 **Verbal Short-term Memory Standard Scores**

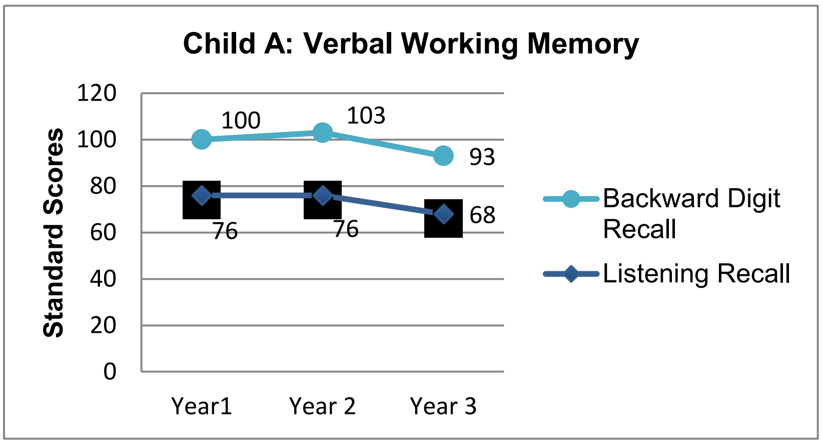

Figure 5.5 **Verbal Working Memory Standard Scores**

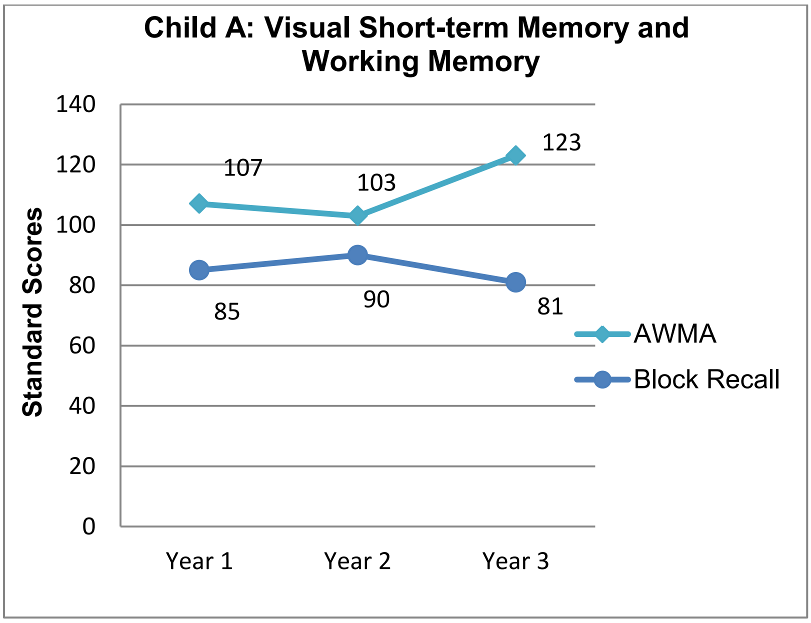

Figure 5.6 **Visual Short-term Memory and Working Memory Standard Scores**

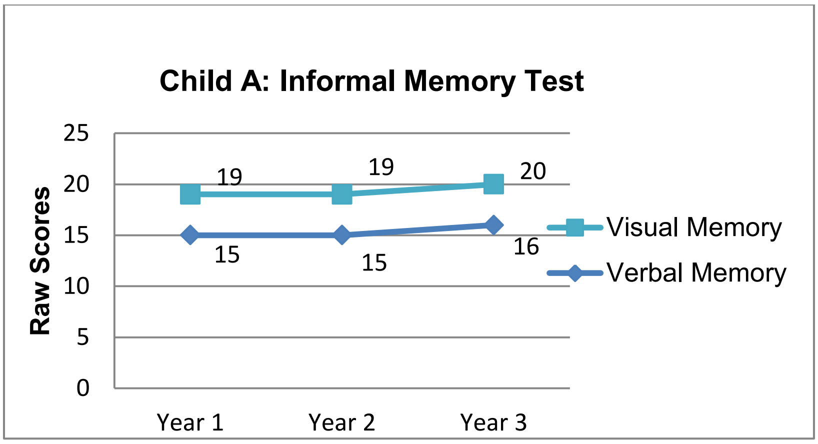

Figure 5.7 **Informal Memory Test Raw Scores**

Child B:

Background from case notes

This teenage girl was the oldest participant in the study, aged 13;10, when she entered the study. Her language and memory abilities were assessed at ages 13;10, 14; 10 and 15;9. At the third data collection point, assessments were administered one month early due to school related demands. She wore a cochlear implant and was educated in a mainstream high school. She received support from the local services for children with hearing impairment and speech and language therapy. From the case notes, her teacher of the hearing-impaired stated that as a young child, Child B found it difficult to combine the single words that she knew into multi-word utterances and therefore remained using single words much longer than expected. Child B also found it difficult to move beyond simple syntactic structures in her use of spoken language.

Table 5.4 ***Child B's annual vocabulary and language assessment results using standard scores***

Assessment	Year 1	Year 2	Year 3
~British Picture Vocabulary Scale 2	65	66	66
^Expressive Vocabulary Test-2	80	80	80
¥*Word Classes Receptive	2	4	8
¥*Understanding Paragraphs	11	13	14
¥+Word Classes Expressive	3	6	11
¥+Recalling Sentences	1	1	2
¥+Formulated Sentences	1	1	1

~ Receptive Vocabulary ^ Expressive Vocabulary ¥ Denotes CELF-4 subtests
* Receptive Language + Expressive Language

Vocabulary and Language

Child B displayed better standard scores in expressive vocabulary than receptive. Her overall receptive vocabulary did not improve over the duration of the study and remained more two standard deviations below the mean (See Table 5.4). Her raw scores for receptive vocabulary (BPVS 2) showed virtually no improvement over the duration of the study (See Table 5.5). However her raw scores on the EVT-2 did. By the end of the study, Child B's standard scores on the Word Classes Receptive and Expressive subtests and Understanding Spoken Paragraph were age appropriate. Her expressive language remained substantially delayed, in relation to the Recalling Sentences and Formulated Sentences subtests on the CELF-4UK. However, her raw scores on these subtests did improve by the completion of the study (See Table 5.5). Table 5.4 summarizes Child B's language assessment results using standard scores over the course of the study.

A comparison of her receptive and expressive vocabulary and language results appear in Figures 5.8, 5.9 and 5.10.

Table 5.5 ***Child B's annual vocabulary, language and memory assessment results using raw scores***

Assessments	Year 1	Year 2	Year 3
Memory Assessments			
Non-word Recall	16	17	17
Word Recall	17	18	19
Digit Recall	30	30	26
Listening Recall	6	18	21
Backward Digit Recall	11	18	19
Block Recall	34	38	38
Odd One Out/AWMA	33	31	Not administered
Vocabulary Assessments			
EVT-2	105	114	115
BPVS 2	95	93	98
Language Assessments			
Receptive			
Word Classes (Receptive)	6	10	15
Understanding Paragraphs	12	13	14
Expressive			
Word Classes (Expressive)	5	8	14
Recalling Sentences	17	23	44
Formulated Sentences	18	15	28

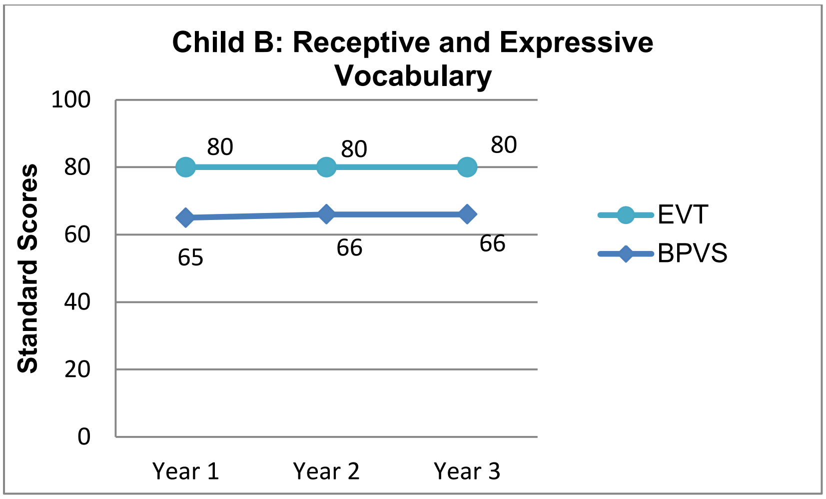

Figure 5.8 **Expressive Vocabulary Test -2 (EVT) and British Picture Vocabulary Test 2 (BPVS) Standard Scores**

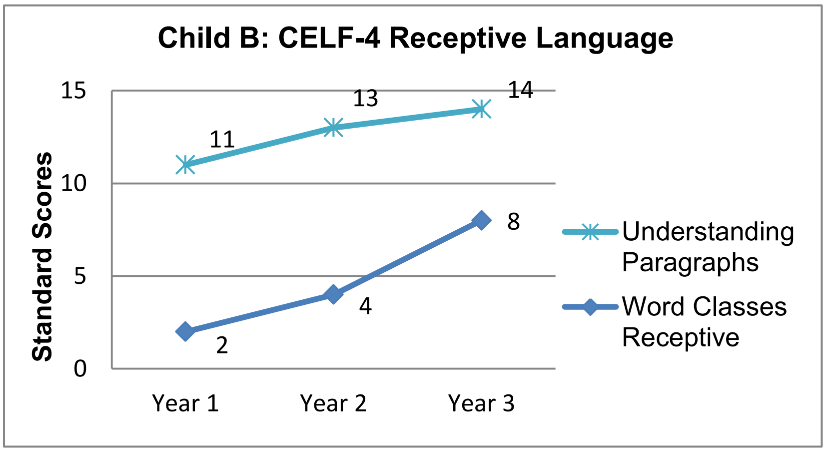

Figure 5.9 **CELF-4UK Receptive Language Standard Scores**

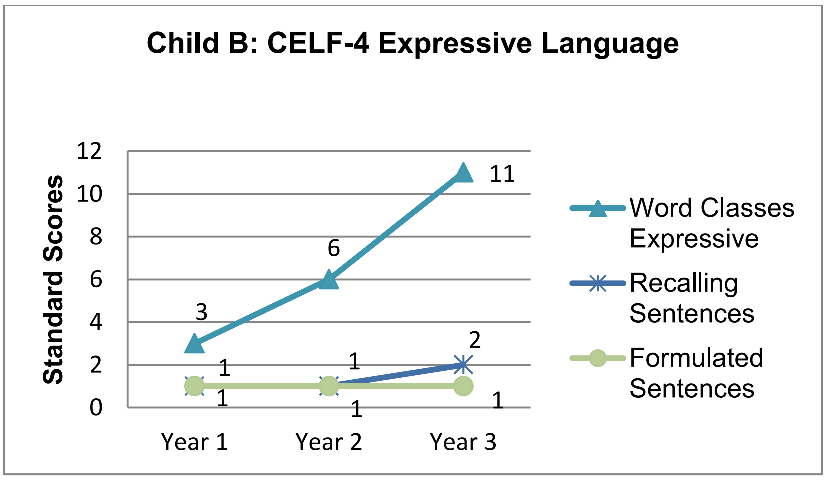

Figure 5.10 **CELF-4UK Expressive Language Standard Scores**

Memory

Throughout the study, Child B demonstrated age appropriate ability to recall non-words, but scores outside normal limits in Word Recall (See Table 5.6). She also exhibited age appropriate skills in verbal working memory (i.e. Listening Recall and Backward Digit Recall). Child B displayed strengths in visual short-term memory and working memory abilities and standard scores well within the normal range. At the third data collection point, the computer programme administering the Odd One Out test from the AWMA became faulty during administration, and therefore the test was not administered. Child B was also unable to complete the Informal Memory Test due to time constraints, needing to attend a lesson in preparation for an exam. The additional demands of mock exams in Year 11, prevented Child B attending an additional session in order to complete the two memory assessments (i.e. Odd One Out test and Informal Memory Test). At ages 13;10 and 14;10 years, she performed slightly better in the visual part of the Informal Memory Test than the verbal. A comparison of verbal and visual short-term memory and working memory tests are in Table 5.6 and Figures 5.11, 5.12, 5.13 and 5.14. The raw scores are in Table 5.5.

Table 5.6 ***Child B's annual memory assessment results using standard scores***

Assessment	Year 1	Year 2	Year 3
±Non-word Recall	97	97	97
±Word Recall	75	75	79
±Digit Recall	90	87	77
∞Backward Digit Recall	82	98	101
∞Listening Recall	90	113	128
+ Block Recall	113	120	120
# Odd One Out	122	121	ND
***Informal Memory Test Visual Score**	24	25	ND
***Informal Memory Test Verbal Score**	22	22	ND

±Verbal Short-term Memory ∞Verbal Working Memory ND: No data

+Visual Short-term Memory #Visual Working Memory * Denotes Raw scores

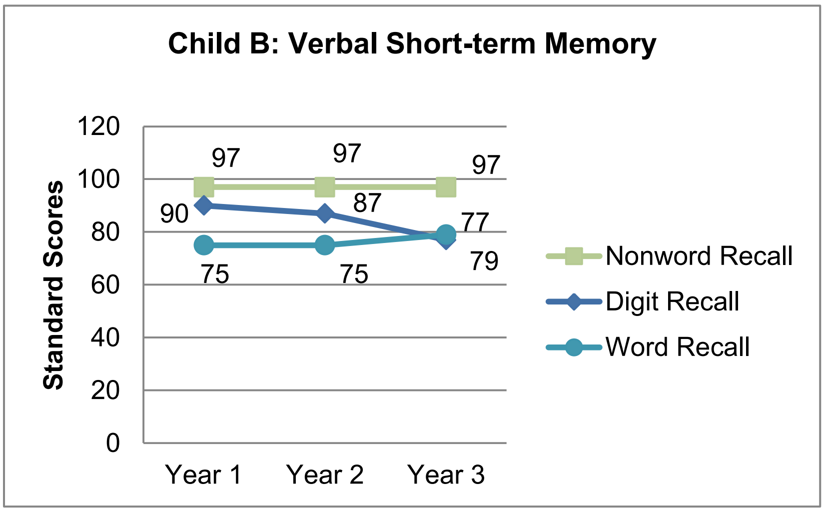

Figure 5.11 **Verbal Short-term Memory Standard Scores**

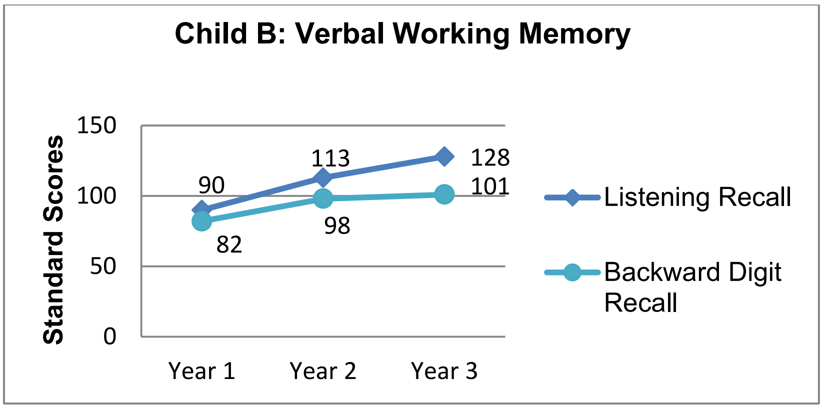

Figure 5.12 **Verbal Working Memory Standard Scores**

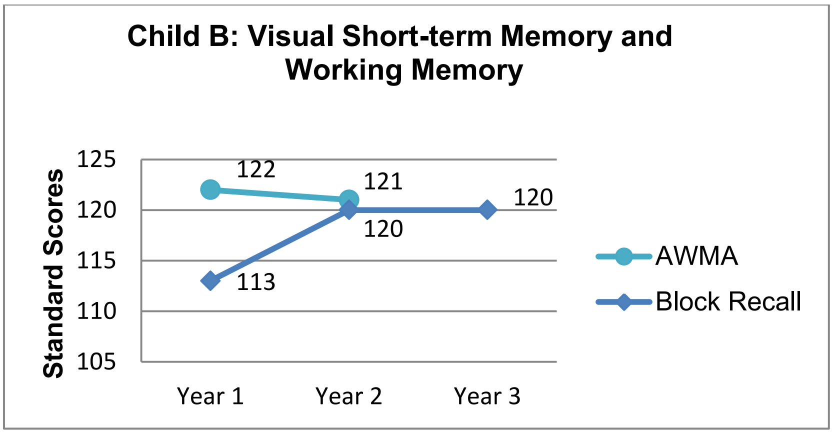

Figure 5.13 **Visual Short-term Memory and Working Memory Standard Scores**

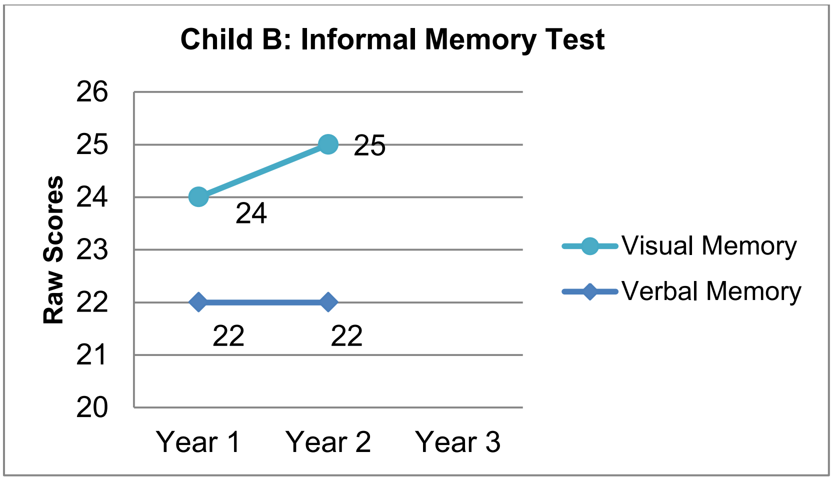

Figure 5.14 **Informal Memory Test Raw Scores**

Child C:

Background from case notes

Child C began the study at the age of 9;9. His language and memory abilities were assessed at ages 9;9, 10;9 and 11;9. He wore a cochlear implant and was educated in a school for children with hearing impairment with class sizes of approximately 7 to 9 students. He received weekly speech and language therapy. At the age of 11;3, he transitioned to a mainstream high school with a resource unit based within the school. From his case notes, his teacher of the hearing-impaired reported that early in his development, Child C found it difficult to learn and retain new vocabulary items that were the focus of therapeutic intervention, despite being able to repeat them.

Table 5.7 ***Child C's annual vocabulary and language assessment results using standard scores***

Assessment	Year 1	Year 2	Year 3
~British Picture Vocabulary Scale 2	66	62	56
^Expressive Vocabulary Test-2	69	71	68
¥*Word Classes Receptive	7	6	4
¥*Understanding Paragraphs	5	6	4
¥+Word Classes Expressive	8	7	5
¥+Recalling Sentences	1	1	1
¥+Formulated Sentences	1	1	1

~ Receptive Vocabulary   ^ Expressive Vocabulary   ¥ Denotes CELF-4 subtests

* Receptive Language   + Expressive Language

Vocabulary and Language

Throughout duration of the study, Child C demonstrated better standard scores in expressive vocabulary than receptive; however, both areas were considerably below average for his age. He did show a small improvement in his raw scores in receptive vocabulary (BPVS 2) and a greater improvement in his raw scores expressive vocabulary (EVT-2) (See Table 5.8). Child C continued to remain substantially delayed in comparison to his normally hearing peers in all areas of receptive and expressive language. By the completion of the study, he appeared to be more delayed than at the beginning of the research study, as he exhibited poorer standard scores across all assessments. However, his raw scores on the Recalling Sentences and Formulating Sentences subtests from the CELF-4UK did improve over the duration of the study (See Table 5.8). Table 5.7 summarizes his assessment results over the course of the study. A comparison of his receptive and expressive vocabulary and language results using standard scores appear in Figures 5.15, 5.16 and 5.17.

Table 5.8 ***Child C's annual vocabulary, language and memory assessment results using raw scores***

Assessments	Year 1	Year 2	Year 3
Memory Assessments			
Non-word Recall	17	18	17
Word Recall	18	21	16
Digit Recall	23	24	24
Listening Recall	0	5	5
Backward Digit Recall	11	7	13
Block Recall	23	30	30
Odd One Out/AWMA	22	23	27
Vocabulary Assessments			
EVT-2	69	77	81
BPVS 2	55	54	58
Language Assessments			
Receptive			
Word Classes (Receptive)	6	7	6
Understanding Paragraphs	5	8	8
Expressive			
Word Classes (Expressive)	5	7	5
Recalling Sentences	11	18	18
Formulated Sentences	7	13	26

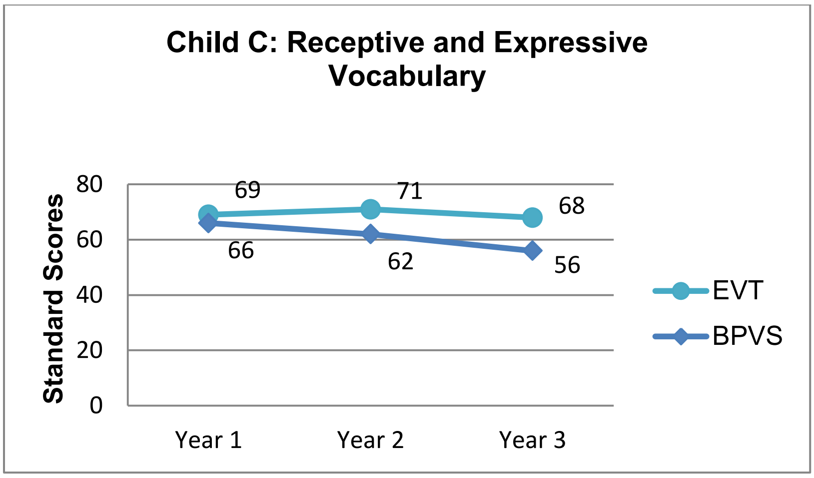

Figure 5.15 **Expressive Vocabulary Test-2 (EVT) and British Picture Vocabulary Scale 2 (BPVS) Standard Scores**

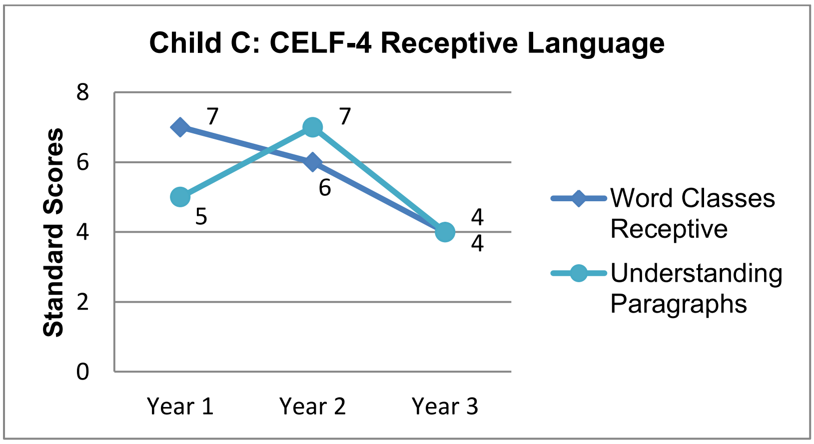

Figure 5.16 **CELF-4UK Receptive Language Standard Scores**

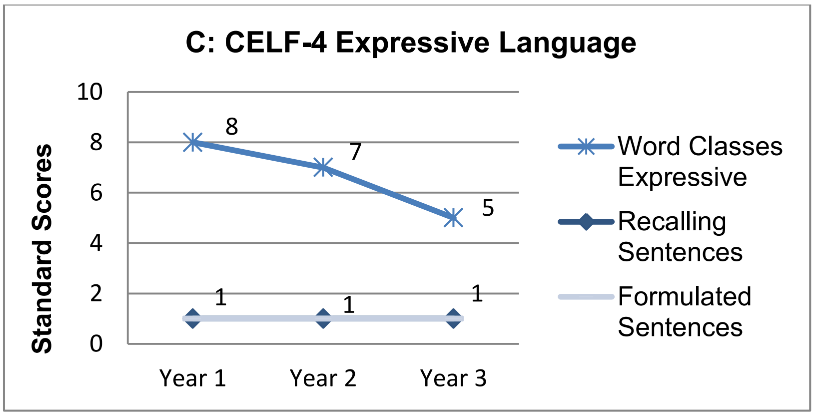

Figure 5.17 **CELF-4UK Expressive Language Standard Scores**

Memory

Child C exhibited age appropriate abilities on the Non-word Recall subtest scoring more than 1 standard deviation above the mean on this test. This is in stark contrast to his standard score of more than 1 standard deviation below the mean on the Digit Recall task. His raw scores on the Listening Recall task did improve, but still remained well outside the normal range for his chronological age with a standard score of 62 (See Table 5.8and Table 5.9). He also displayed strengths in visual short-term memory and working memory. With regard to the Block Recall task in Year 1, Child C became ill at the end of the administration of this subtest. This may have affected his performance on this test. Child C achieved higher raw scores on the visual part of Informal Memory Test than the verbal section. Over the duration of the study, both his visual and verbal raw scores improved, but the visual score remained higher throughout the study. A comparison of verbal and visual short-term memory and working memory tests are in Table 5.9 and Figures 5.18, 5.19, 5.20 and 5.21.

Table 5.9 ***Child C's annual memory assessment results using standard scores***

Assessment	Year 1	Year 2	Year 3
±Non-word Recall	117	118	113
±Word Recall	90	98	81
±Digit Recall	81	85	76
∞Backward Digit Recall	89	68	88
∞Listening Recall	62	62	62
+ Block Recall	^81	105	105
# Odd One Out	113	112	117
***Informal Memory Test Visual Score**	17	19	22
***Informal Memory Test Verbal Score**	12	12	16

±Verbal Short-term Memory ∞Verbal Working Memory * Denotes Raw scores

+Visual Short-term Memory #Visual Working Memory

^Child C became ill directly after the administration of this subtest

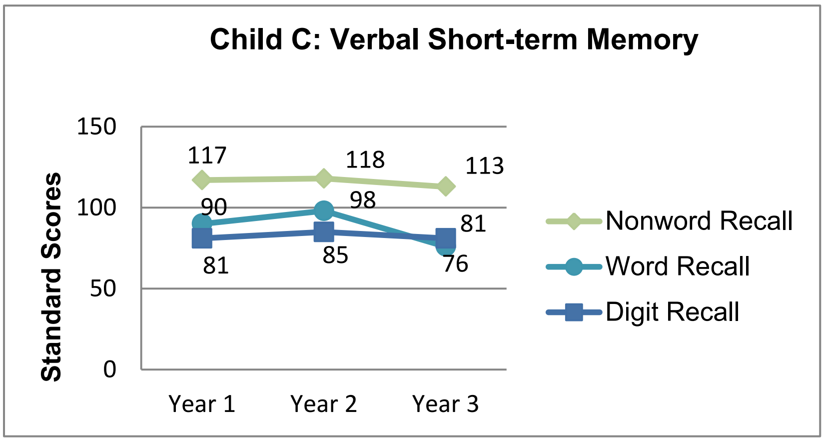

Figure 5.18 **Verbal Short-term Memory Standard Scores**

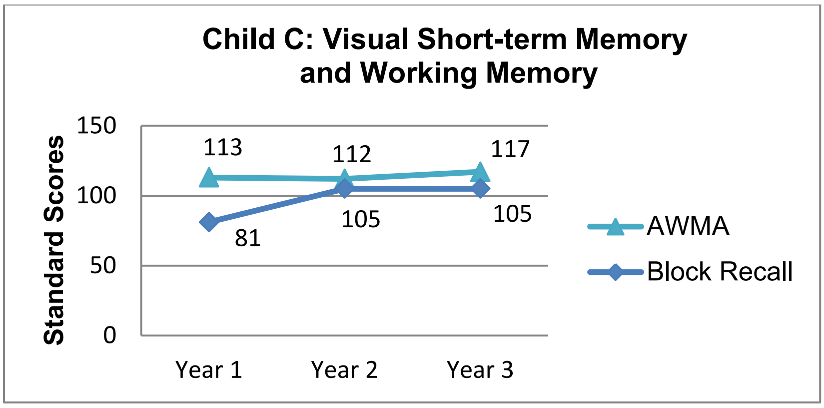

Figure 5.19 **Visual Short-term Memory and Working Memory Standard Scores**

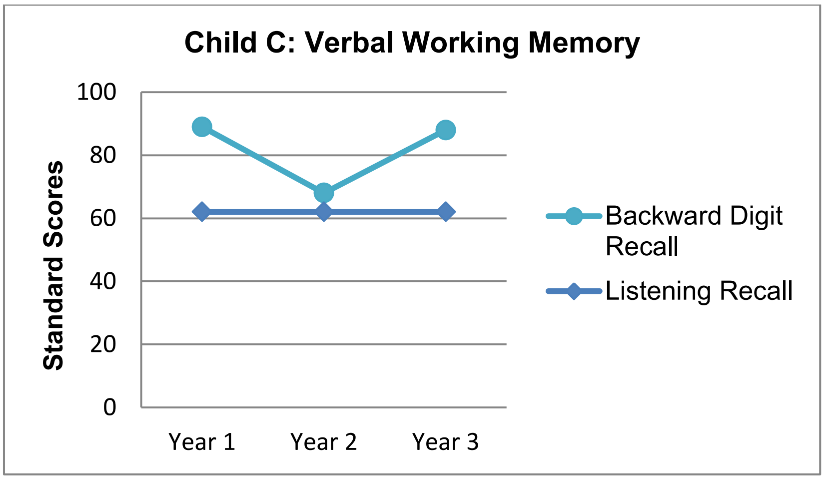

Figure 5.20 **Verbal Working Memory Standard Scores**

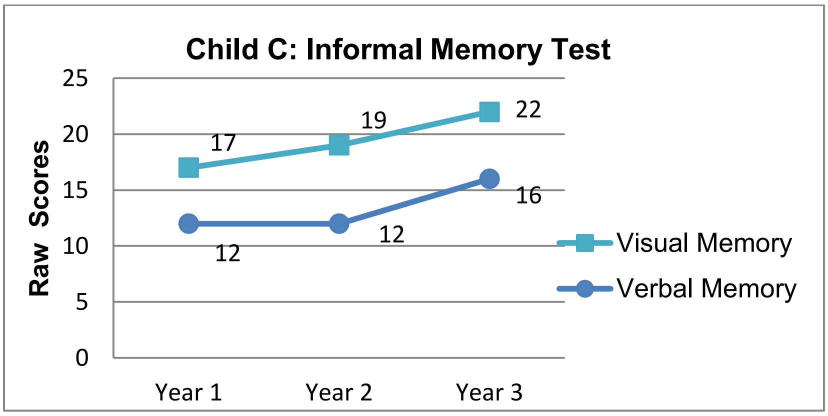

Figure 5.21 **Informal Memory Test Raw Scores**

Child D:

Background from case notes

Child D began the study at the age of 10;3. His language and memory abilities were assessed at ages 10;3, 11;3 and 12;3. He had a severe bilateral hearing loss, with a moderate hearing loss in the high frequencies. He wore hearing aids and was educated in a school for children with hearing impairment, with class sizes of approximately 7 to 9 students. At the age of 11;9, he transitioned to a mainstream high school with a resource provision based with the school. He attended weekly speech and language therapy sessions, whilst attending primary school. Information from his case notes from his speech and language therapist stated that as a young child, he found it difficult learning new vocabulary items and required extensive repetition in order to acquire a new word.

Table 5.10 *Child D's annual vocabulary and language assessment results using standard scores*

Assessment	Year 1	Year 2	Year 3
~British Picture Vocabulary Scale 2	71	66	69
^Expressive Vocabulary Test-2	77	75	79
¥*Word Classes Receptive	3	6	4
¥*Understanding Paragraphs	7	7	6
¥+Word Classes Expressive	4	8	4
¥+Recalling Sentences	1	1	1
¥+Formulated Sentences	1	1	1

~ Receptive Vocabulary ^ Expressive Vocabulary ¥ Denotes CELF-4 subtests

* Receptive Language + Expressive Language

Vocabulary and Language

Throughout the duration of the study, Child D exhibited greater standard scores on the EVT-2 than the BPVS 2. However, both remained more than 1 standard deviation below the mean throughout the study. He did, however, show an improvement in his raw scores on both of the vocabulary assessments (See Table 5.11). His receptive and expressive language continued to develop slowly, but he did not reach age appropriate levels by the completion of the study. His scores were well below average for his chronological age. His raw scores on the Understanding Paragraphs subtest (receptive language task) and both the Recalling Sentences and the Formulating Sentences test did improve of the course of the study (See Table 5.11). Table 5.10 summarizes his assessment results over the duration of the study. A comparison of his receptive and expressive vocabulary and language results using standard scores appear in Figures 5.22, 5.23 and 5.24.

Table 5.11 ***Child D's annual vocabulary, language and memory assessment results using raw scores***

Assessments	Year 1	Year 2	Year 3
Memory Assessments			
Non-word Recall	14	13	17
Word Recall	15	15	15
Digit Recall	18	19	20
Listening Recall	6	6	12
Backward Digit Recall	7	6	6
Block Recall	23	31	37
Odd One Out/AWMA	20	26	30
Vocabulary Assessments			
EVT-2	77	80	95
BPVS 2	53	55	65
Language Assessments			
Receptive			
Word Classes (Receptive)	2	7	6
Understanding Paragraphs	7	8	10
Expressive			
Word Classes (Expressive)	2	7	4
Recalling Sentences	10	15	15
Formulated Sentences	9	14	15

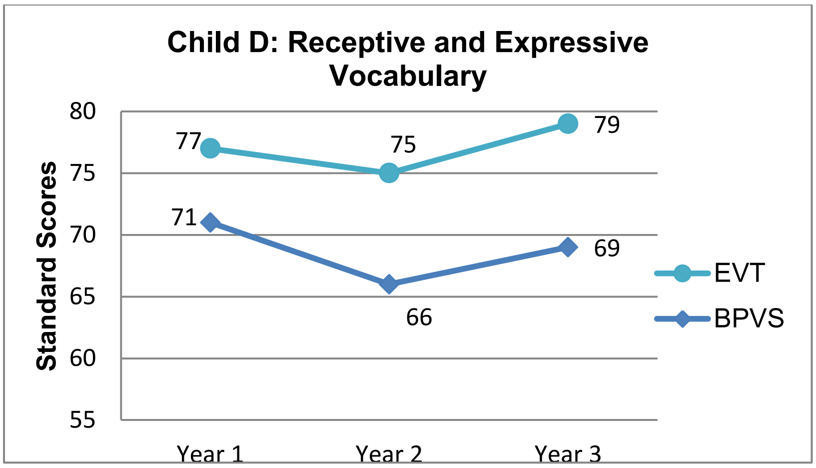

Figure 5.22 **Expressive Vocabulary Test-2 (EVT) and British Picture Vocabulary Scale 2 (BPVS) Standard Scores**

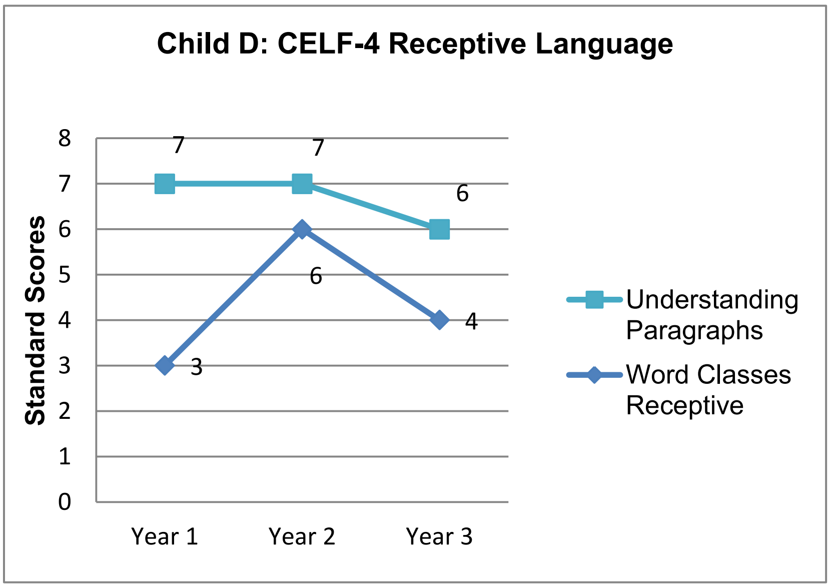

Figure 5.23 **CELF-4UK Receptive Language Standard Scores**

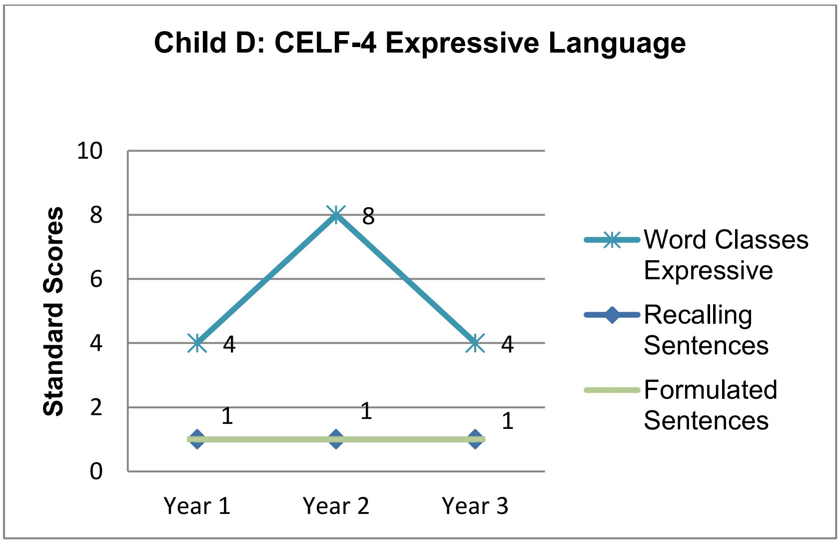

Figure 5.24 **CELF-4UK Expressive Language Standard Scores**

Memory

Throughout the duration of the study, Child D achieved standard scores within normal limits in the Non-word Recall task. However, his standard scores on the Word Recall and Digit Recall tests were more approximately 2 standard deviations below the mean. Child D achieved the virtually no change in his raw scores for both of these tests throughout the study. He also exhibited delays in verbal working memory, but did achieve and age appropriate score in the Listening Recall task by the final year of the study. He exhibited visual short-term memory and working memory abilities more than 1 standard deviation above the mean over the course of the study (i.e. Block Recall and Odd One Out). His standard scores showed an improvement over the course of the study (See Table 5.12 below). Child D achieved higher raw scores on the visual part of the Informal Memory Test than the verbal test. This pattern was observed in Year 1 of the study and continued throughout the duration of the study. A comparison of verbal and visual short-term memory and working memory tests are in Figures 5.25, 5.26, 5.27 and 5.28.

Table 5.12 ***Child D's annual memory assessment results using standard scores***

Assessment	Year 1	Year 2	Year 3
±Non-word Recall	101	95	113
±Word Recall	78	78	71
±Digit Recall	60	66	70
∞Backward Digit Recall	75	66	64
∞Listening Recall	72	68	90
+ Block Recall	90	124	126
# Odd One Out	108	126	133
***Informal Memory Test Visual Score**	20	21	21
***Informal Memory Test Verbal Score**	16	16	15

±Verbal Short-term Memory
+Visual Short-term Memory
∞Verbal Working Memory
#Visual Working Memory
* Denotes Raw scores

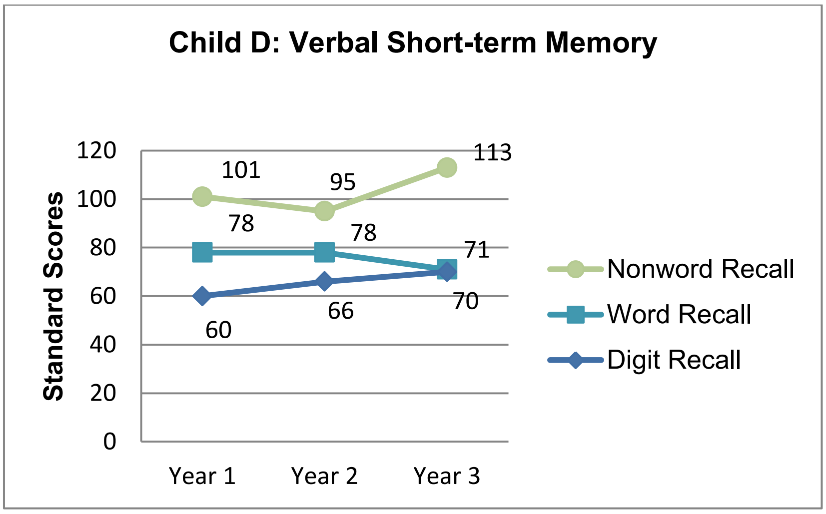

Figure 5.25 **Verbal Short-term Memory Standard Scores**

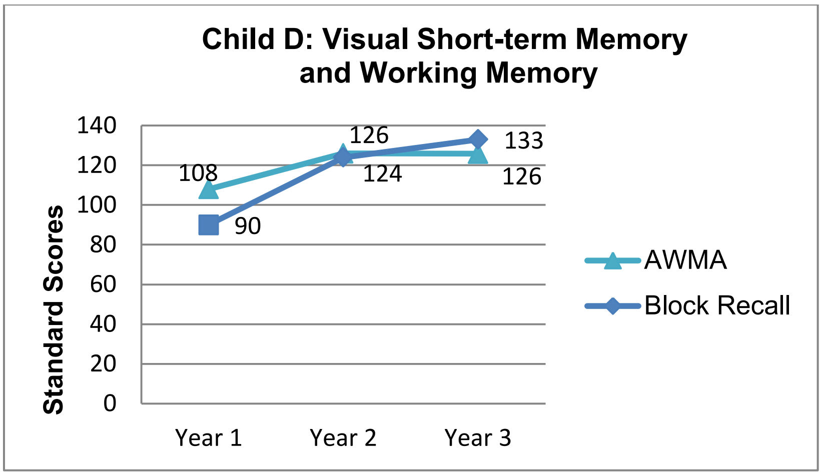

Figure 5.26 **Visual Short-term Memory and Working Memory Standard Scores**

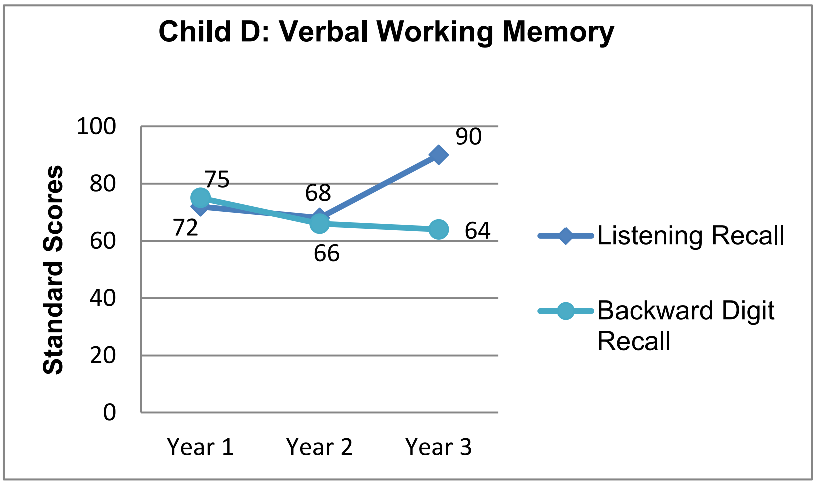

Figure 5.27 **Verbal Working Memory Standard Scores**

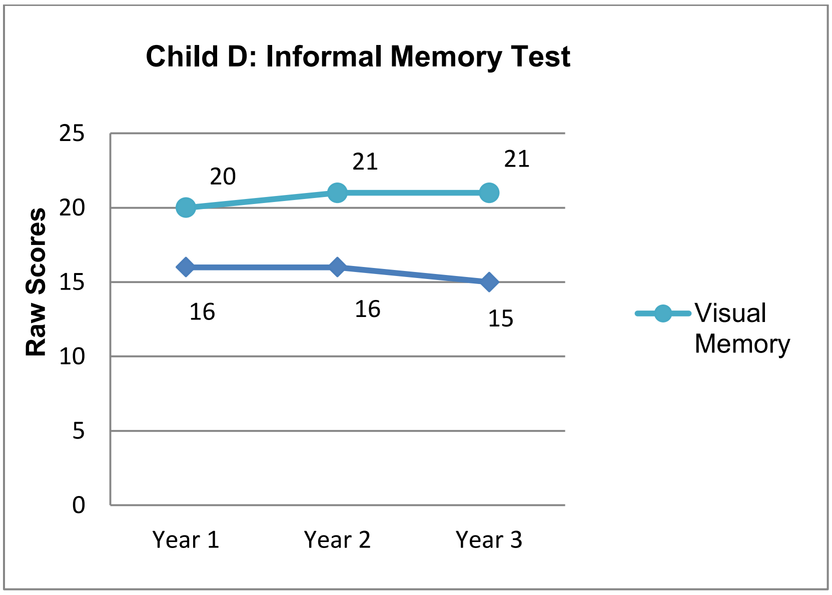

Figure 5.28 **Informal Memory Test Raw Scores**

Child E:

Background from case notes

Child E attended a mainstream primary school and received support from the local services for children with hearing impairment and speech and language therapy. She began the research study at the age of 9;11. Her language and memory abilities were assessed at ages 9;11, 10;11 and 11;11. At the start of the study, Child E had a severe to profound, bilateral hearing loss, which deteriorated in the final year of the study. Her hearing aids were of limited benefit and she was under assessment for bilateral cochlear implantation. As a result of her limited access to sound, she was unable to complete the CELF-4UK assessments at the third data collection point. Similar to the other children in this study, Child E had a history of considerable word learning difficulties as a young child, which continued throughout her education.

Table 5.13 ***Child E's annual vocabulary and language assessment results using standard scores***

Assessment	Year 1	Year 2	Year 3
~British Picture Vocabulary Scale 2	66	68	71
^Expressive Vocabulary Test-2	77	80	92
¥*Word Classes Receptive	7	5	ND
¥*Understanding Paragraphs	2	2	ND
¥+Word Classes Expressive	8	4	ND
¥+Recalling Sentences	2	2	ND
¥+Formulated Sentences	2	2	ND

~ Receptive Vocabulary
* Receptive Language
^ Expressive Vocabulary
+ Expressive Language
¥ Denotes CELF-4 subtests
ND: No data

Vocabulary and Language

Throughout the duration of the study, Child E displayed better expressive vocabulary than receptive. Her expressive vocabulary improved over the duration of the project, to be within normal limits for her chronological age by the final year of the study. Her raw scores on the BPVS 2 (receptive vocabulary) also showed an improvement (See Table 5.14), but her standard scores remained more than 2 standard deviations below the mean for her chronological age. Child E's expressive and receptive language remained considerably delayed as her standard scores were more than 1 standard deviation below the mean. Her raw scores on the Recalling Sentences and Formulating Sentences test did show an improvement in her expressive language abilities (See Table 5.14). Table 5.13 presents a summary of her assessment results over the period of the study). A comparison of her receptive and expressive vocabulary and language results using standard scores appear in Figures 5.29, 5.30 and 5.31.

Table 5.14 ***Child E's annual vocabulary, language and memory assessment results using raw scores***

Assessments	Year 1	Year 2	Year 3
Memory Assessments			
Non-word Recall	18	27	19
Word Recall	21	18	15
Digit Recall	30	33	31
Listening Recall	10	10	12
Backward Digit Recall	12	15	11
Block Recall	27	27	29
Odd One Out/AWMA	19	23	24
Vocabulary Assessments			
EVT-2	84	95	116
BPVS 2	56	69	91
Language Assessments			
Receptive			
Word Classes (Receptive)	6	5	Not Administered
Understanding Paragraphs	2	2	Not Administered
Expressive			
Word Classes (Expressive)	5	3	Not Administered
Recalling Sentences	27	36	Not Administered
Formulated Sentences	10	13	Not Administered

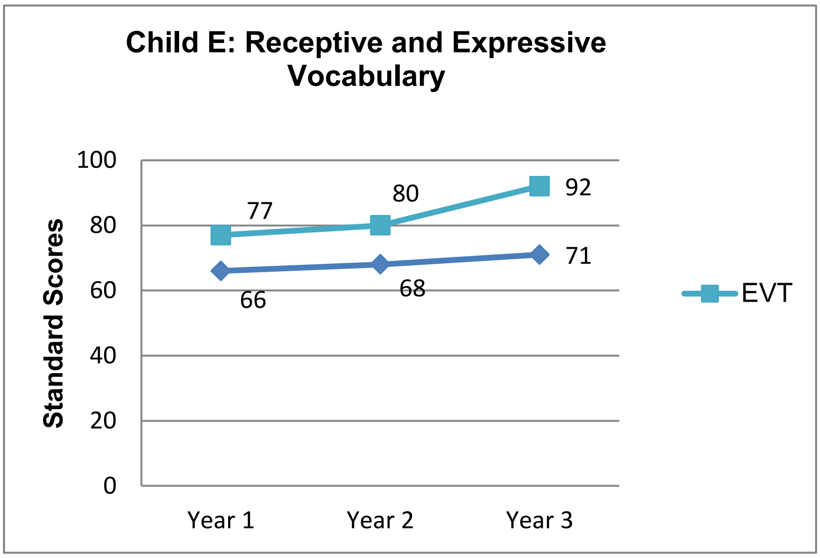

Figure 5.29 **Expressive Vocabulary Test-2 (EVT) and British Picture Vocabulary Scale 2 (BPVS) Standard Scores**

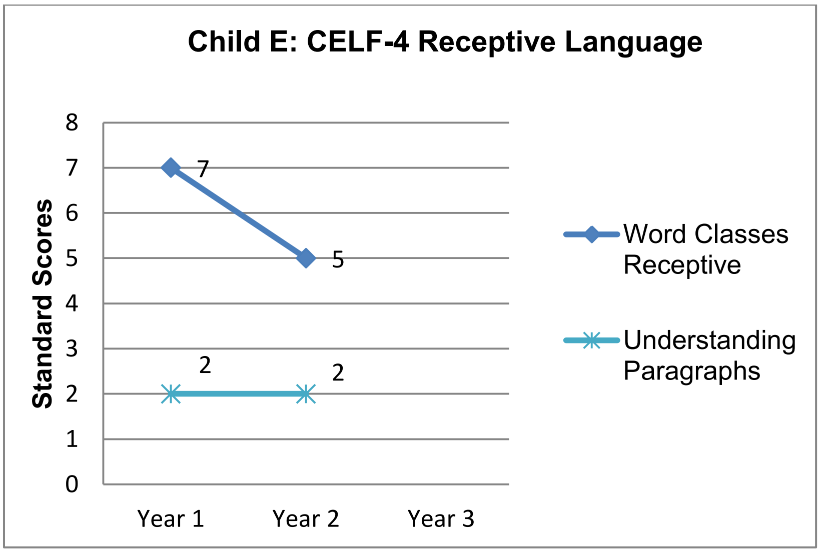

Figure 5.30 **CELF-4UK Receptive Language Standard Scores**

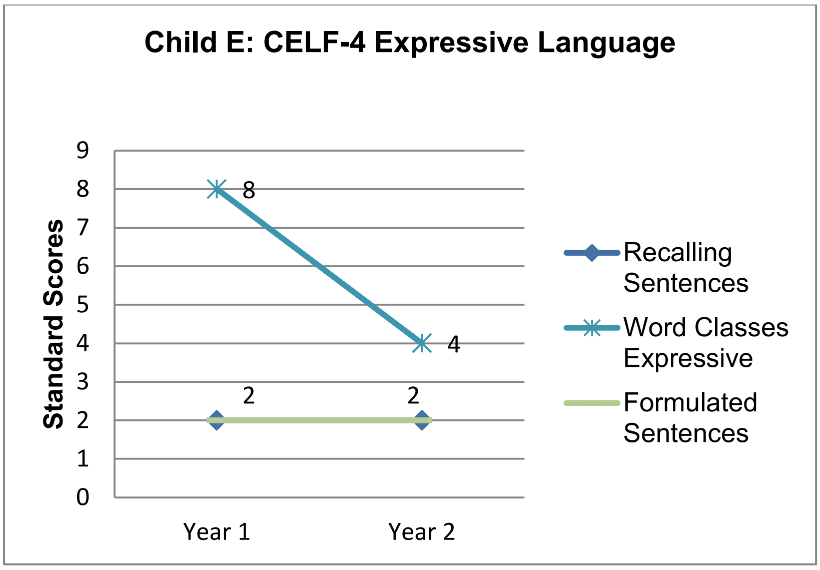

Figure 5.31 **CELF-4UK Expressive Language Standard Scores**

Memory

Throughout the entirety of the study, Child E displayed age appropriate skills in Non-word and Digit Recall, but poorer scores on Word Recall. She achieved higher scores on the Non-word Recall subtest than the Digit Recall test, with standard scores of 2 standard deviations above the mean (See Table 5.15). Her scores on verbal short-term memory and working memory varied from year to year to be within normal limits on two of the three testing sessions. However, the Word Recall results were the poorest of all the verbal short-term memory measures. Child E exhibited standard scores more than 1 standard deviation above the mean in visual short-term memory and working memory. Over the course of the study, Child E consistently did better in the visual task than the verbal task on the Informal Memory Test. A comparison of her verbal and visual short-term memory and working memory tests are in Figures 5.32, 5.33, 5.34 and 5.35. The raw scores appear in Table 5.14.

Table 5.15 ***Child E's annual memory assessment results using standard scores***

Assessment	Year 1	Year 2	Year 3
±Non-word Recall	123	93	124
±Word Recall	101	85	71
±Digit Recall	108	108	99
∞Backward Digit Recall	93	95	81
∞Listening Recall	90	77	90
+ Block Recall	102	93	101
# Odd One Out	106	114	101
***Informal Memory Test Visual Score**	13	21	21
***Informal Memory Test Verbal Score**	9	16	17

±Verbal Short-term Memory ∞Verbal Working Memory * Denotes Raw scores

+Visual Short-term Memory #Visual Working Memory

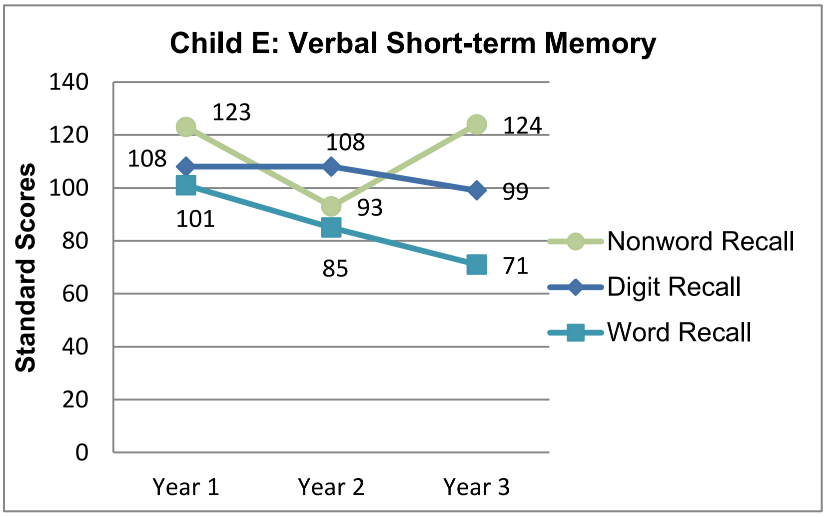

Figure 5.32 **Verbal Short-term Memory Standard Scores**

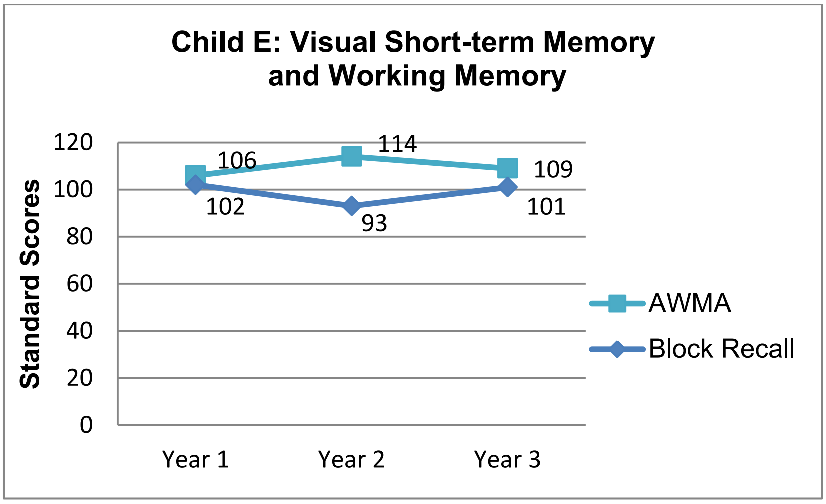

Figure 5.33 **Visual Short-term Memory and Working Memory Standard Scores**

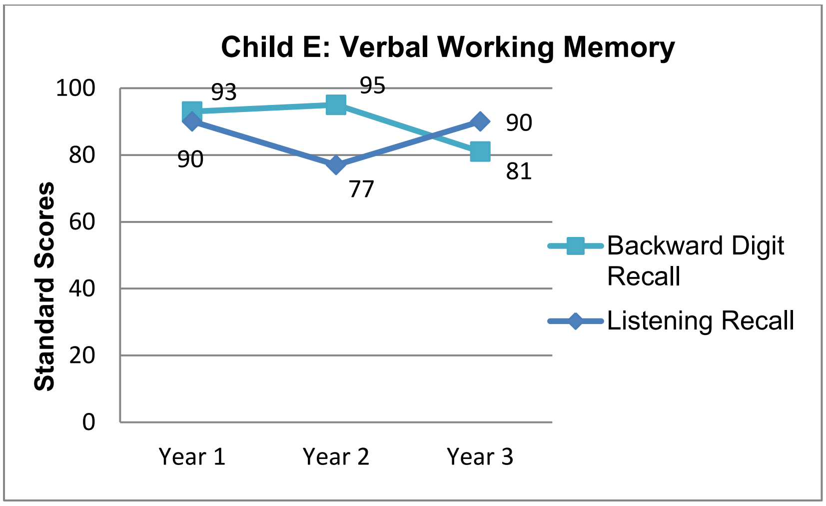

Figure 5.34 **Verbal Working Memory Standard Scores**

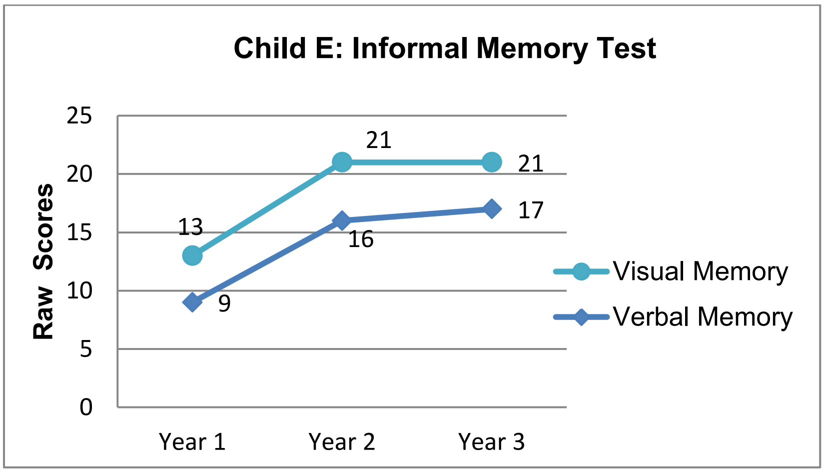

Figure 5.35 **Informal Memory Test Raw Scores**

Child F:

Background from case notes

Child F began the study at the age of 9;4. His language and memory abilities were assessed at ages 9;4, 10;4 and 11;4. He used a cochlear implant to access spoken language. He was educated in a school for children with hearing impairment, with class sizes of approximately 7 to 9 students. He transitioned in Year 7 (i.e. at age 11;10) to a mainstream high school with a resource provision for children with hearing impairment. Child F attended weekly speech and language therapy sessions throughout primary school. In the case notes, his teacher reported that as a young child, he found it extremely difficult to learn new words and required regular repetition of targeted vocabulary in order to retain any new words.

Table 5.16 ***Child F's annual vocabulary and language assessment results using standard scores***

Assessment	Year 1	Year 2	Year 3
~British Picture Vocabulary Scale 2	71	68	62
^Expressive Vocabulary Test-2	76	75	76
¥*Word Classes Receptive	7	6	6
¥*Understanding Paragraphs	3	6	5
¥+Word Classes Expressive	4	8	8
¥+Recalling Sentences	1	1	1
¥+Formulated Sentences	1	1	1

~ Receptive Vocabulary ^ Expressive Vocabulary ¥ Denotes CELF-4 subtests
* Receptive Language + Expressive Language

Vocabulary and Language

Throughout the duration of the study, Child F exhibited greater standard scores on the EVT-2 than the BPVS 2. However, both his receptive and expressive vocabulary scores persisted in being more than 1 standard deviation below the mean throughout the course of the study. His standard scores were also more than 1 standard deviation below the mean for his chronological age in all areas of receptive and expressive language development with the exception of Word Classes Expressive, which was within normal limits at data collection points two and three of the study. He did, however, show an improvement in his raw scores on both the Recall Sentences and Formulating Sentences subtest from the CELF-4UK (See Table 5.17 for raw scores). Table 5.16 represents a summary of his assessment results over the time of the study. A comparison of his receptive and expressive vocabulary and language results using standard scores appear in Figures 5.36, 5.37 and 5.38.

Table 5.17 ***Child F's annual vocabulary, language and memory assessment results using raw scores***

Assessments	Year 1	Year 2	Year 3
Memory Assessments			
Non-word Recall	17	20	17
Word Recall	12	18	14
Digit Recall	21	24	17
Listening Recall	6	8	9
Backward Digit Recall	9	14	18
Block Recall	29	28	29
Odd One Out/AWMA	33	30	30
Vocabulary Assessments			
EVT-2	79	83	91
BPVS 2	58	60	58
Language Assessments			
Receptive			
Word Classes (Receptive)	6	7	7
Understanding Paragraphs	3	6	9
Expressive			
Word Classes (Expressive)	6	7	7
Recalling Sentences	8	9	13
Formulated Sentences	8	10	12

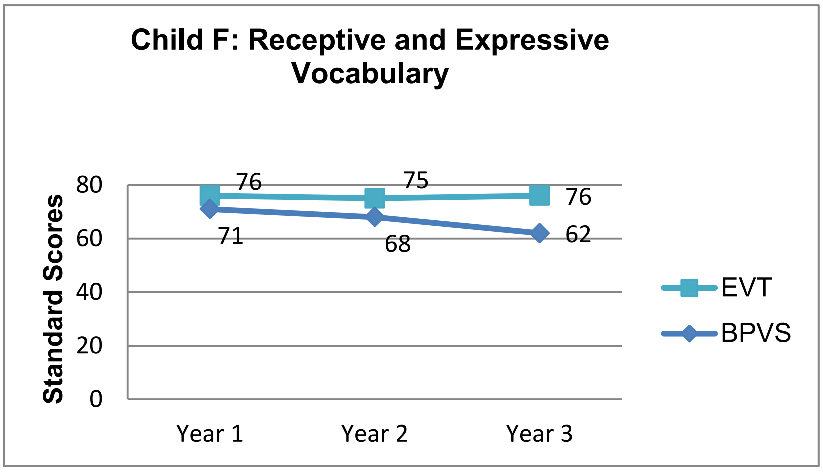

Figure 5.36 **Expressive Vocabulary Test-2 (EVT) and British Picture Vocabulary Scale 2 (BPVS) Standard Scores**

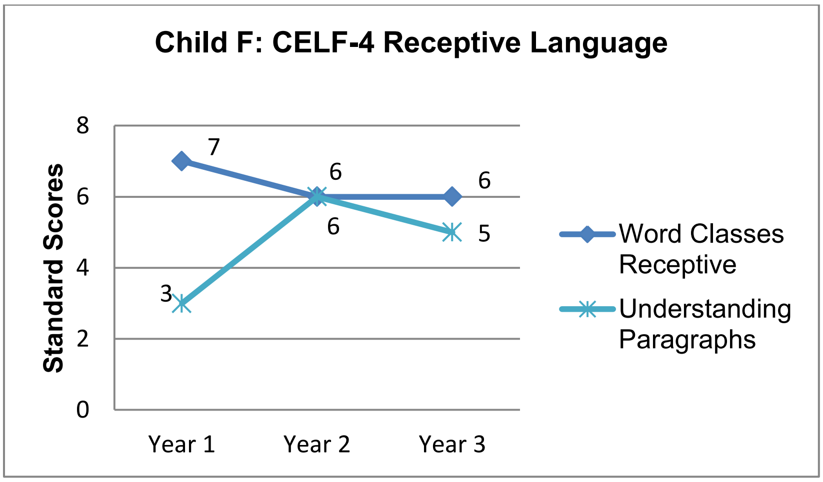

Figure 5.37 **CELF-4UK Receptive Language Standard Scores**

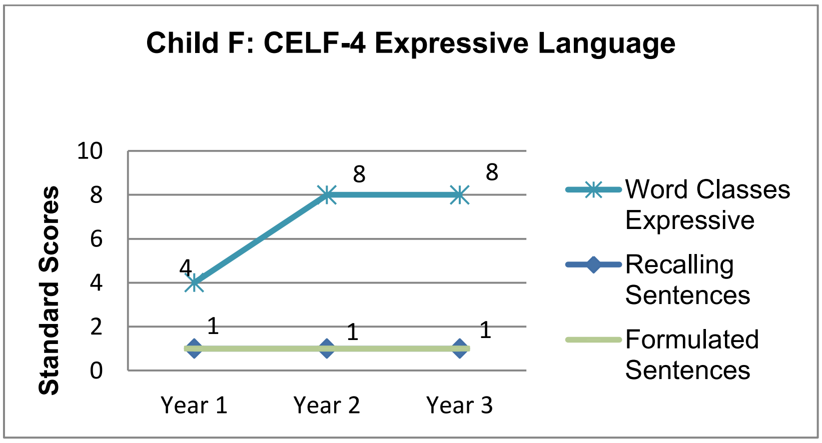

Figure 5.38 **CELF-4UK Expressive Language Standard Scores**

Memory

Throughout the study, Child F achieved scores more than 2 standard deviations above the mean on the Non-word Recall task. His standard scores on the Word and Digit Recall tasks were between 1 to 2 standard deviations below the mean, with the exception of the second data collection point, where his scores were within normal limits. He displayed age appropriate abilities on the Backward Digit Recall task (i.e. verbal working memory), but standard scores more than 1 standard deviation below the mean in the Listening Recall task. Child F also exhibited age appropriate abilities in both visual short-term memory and working memory (See Table 5.18 below). Child F achieved higher raw scores in the visual part of the Informal Memory Test than the verbal test. A comparison of his verbal and visual short-term memory and working memory tests are in Figures 5.39, 5.40, 5.41 and 5.42. The raw scores appear in Table 5.17.

Table 5.18 ***Child F's annual memory assessment results using standard scores***

Assessment	Year 1	Year 2	Year 3
±Non-word Recall	118	134	113
±Word Recall	65	90	67
±Digit Recall	73	85	62
∞Backward Digit Recall	83	103	105
∞Listening Recall	72	79	71
+ Block Recall	113	108	101
# Odd One Out	116	132	126
***Informal Memory Test Visual Score**	19	21	24
***Informal Memory Test Verbal Score**	19	15	19

±Verbal Short-term Memory ∞Verbal Working Memory * Denotes Raw scores

+Visual Short-term Memory #Visual Working Memory

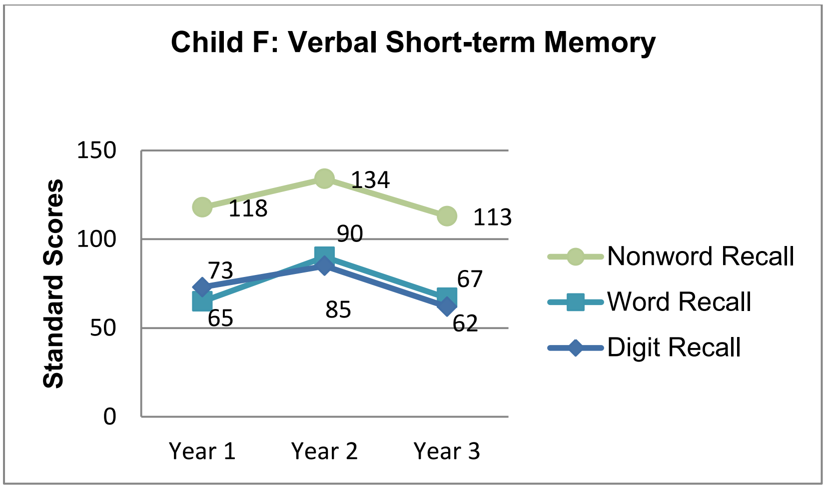

Figure 5.39 **Verbal Short-term Memory**

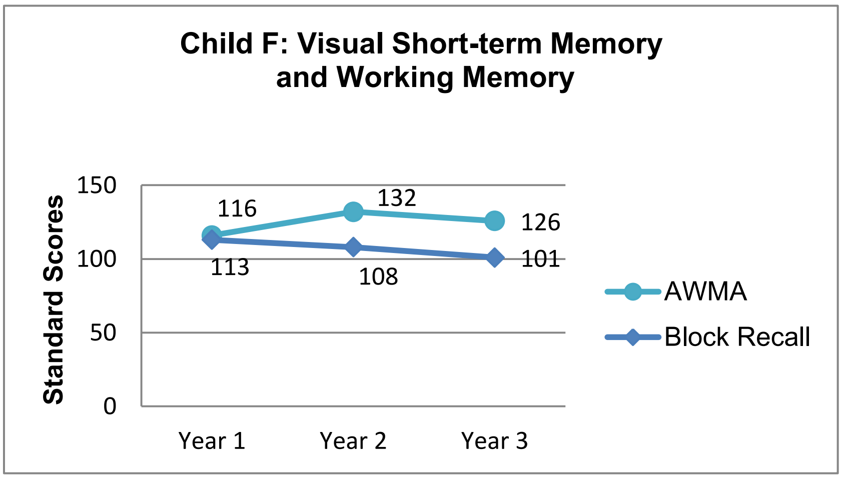

Figure 5.40 **Visual Short-term Memory and Working Memory**

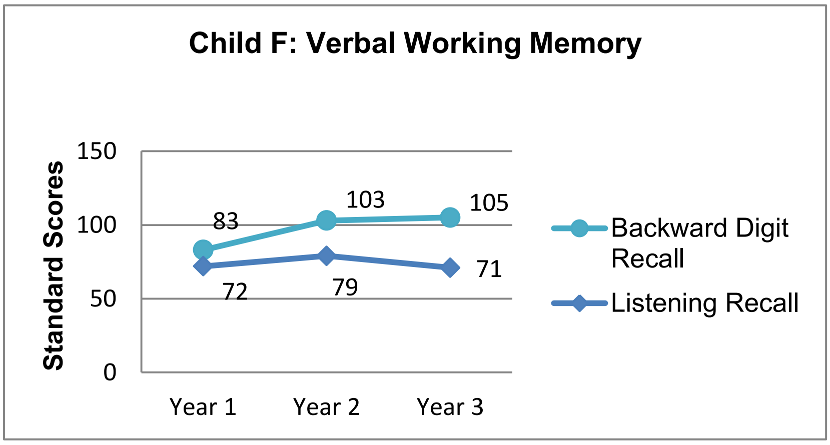

Figure 5.41 **Verbal Working Memory**

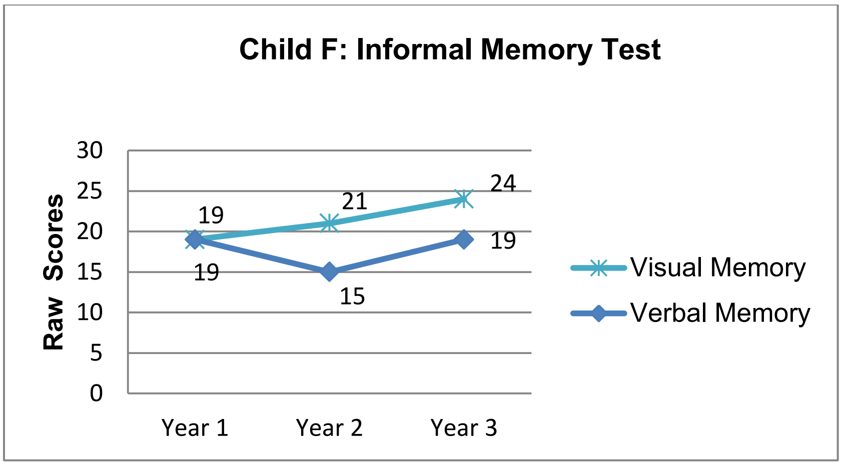

Figure 5.42 **Informal Memory Test Raw Scores**

5.3 Summary of the individual participant's vocabulary, language and memory abilities

Vocabulary and Language

In summary, the profile that has emerged from the results of the study is that each of the children continued to exhibit better expressive vocabulary than receptive, but both standard scores remained more than 1 standard deviation below the mean. The children's raw score in relation to expressive vocabulary did increase, but this improvement was not evident when analysing standard scores, which compare the children to their normally hearing peers of the same age. This pattern persisted throughout the entirety of the study. Their pattern of vocabulary development did not change with the exception of Child E, who achieved age appropriate expressive vocabulary by the third year of the study. With regard to expressive and receptive vocabulary and language abilities of the cohort of children, there was little improvement in the participants' standard scores over the duration of the project. However, all six of the children did show an improvement in their raw scores on both the Recalling Sentences and Formulating Sentences subtests (expressive language). That is to say, that all of the children achieved more correct responses on these tests from year to year, but did not reach age appropriate levels.

Memory

All six children exhibited weaknesses in the Word Recall test (i.e. verbal short-term memory task), which assesses the quality of both phonological and lexical representations in the long term memory. The verbal and visual short-term memory and working memory abilities of these children did not alter considerably over the duration of the study despite their very different ages (i.e. 8;5 to 15;9 years). On the Informal Memory Test visual part, the children either maintained their score or improved it over the course of the study. With regard to the verbal aspect of the assessment, three of the six children showed a small improvement in their raw score. The pattern demonstrated throughout the research study for all six children was that they consistently performed better in the visual task than the verbal task.

5.4 Group results for vocabulary and language

The following two sections will discuss the group vocabulary, language and memory results for this cohort of children with hearing impairment and additional language learning difficulties LLD with reference to research objectives 1 and 2 restated below.

1. To profile memory, vocabulary and language development within a longitudinal study
2. To investigate what aspects of vocabulary, language and memory are impacting upon the development of these children

This section (5.4) will outline the areas of vocabulary and language in which there are noteworthy differences in receptive and expressive abilities. In the following two sections (5.5 and 5.6), the strengths and/or weakness in visual and verbal memory short-term memory and working memory for this cohort of children will be presented. The memory profile for this group of children with hearing impairment and additional LLD will be addressed in the final part of this chapter.

5.4.1 Receptive and expressive vocabulary results

The year-by-year group means and standard deviations for the BPVS 2 and EVT-2 are presented in Table 5.19 (See also Appendix 3). A two by three repeated measures analysis of variance (ANOVA) was conducted to compare standard scores on the BPVS 2 and the EVT-2 across the three data collection points; There was no significant main effect for year, but there was a significant main effect for tests; $F(1,5) = 58.584$, $p=.001$ regardless of the year (See Figure 5.43). Children performed significantly better on the expressive vocabulary test (i.e. EVT-2) than the receptive vocabulary test (i.e. BPVS 2). There was also a significant interaction between years and tests; $F(2,10) = 6.712$, $p=.014$. It is evident that the group means increase year on year for the EVT-2, which is in contrast to the BPVS whereby the group mean standard scores decrease (See Table 5.19 below). Using Cohen's (1988) conventions, this may be described as a medium positive difference through to a large positive difference.

Table 5.19 *Standard score descriptive statistics, mean differences and effect sizes for the BPVS 2 and the EVT-2*

	BPVS	EVT	*r*	*Mean Diff*	*D*	*N*
Year 1	67.500 *SD*(2.739)	74.833 *SD*(4.355)	.19	7.33 95%CI [2.43, 12.24]	1.80 95%CI [0.47, 3.14]	6
Year 2	66.833 *SD*(2.994)	75.333 *SD*(4.033)	.07	6.5 95%CI [1.42, 11.58]	1.64 95%CI [0.33,2.94]	6
Year 3	63.167 *SD*(6.676)	78.167 *SD*(8.010)	.85	14.997 95%CI [10.59, 9.40]	1.82 95%CI [0.68,2.96]	6
Mean over 3 Years	66.5 *SD*(4.14)	76.11 *SD*(5.47)	.37	9.61 95%CI [3.84,15.38]	1.77 95%CI [0.54,3.01]	6

*equally weighted *SD*s, sample size adjusted and independent of sample *r* (See Bonett, 2009 for relevant formulae).

SD=Standard Deviation *N*=Number *r*=correlation *d*=effect size

CI=confidence interval

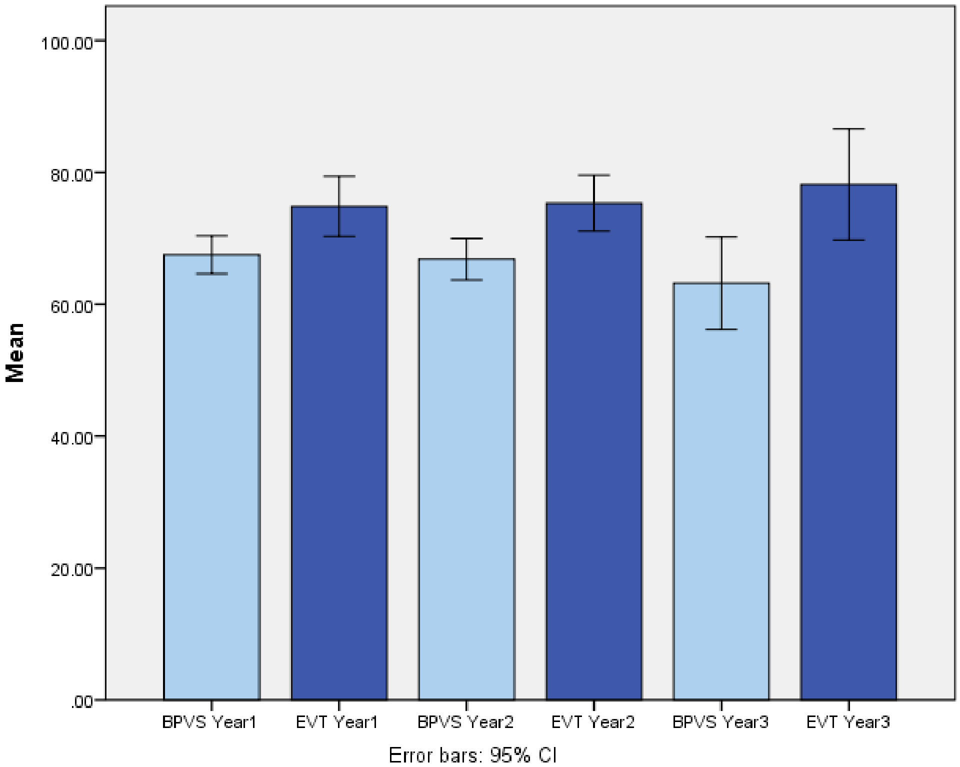

Figure 5.43 **Group mean standard scores for the BPVS 2 and the EVT-2**

5.4.2 Receptive language results

The Word Classes (Receptive) and Understanding Paragraphs subtests from the CELF-4UK assess different aspects of comprehension. The Word Classes (Receptive) task is reliant upon vocabulary development and knowledge of words and their relationships to one another. This is considerably different from the Understanding Paragraphs test that examines comprehension of the text and making inferences. The mean and standard deviation for the receptive tests for the group are in Table 5.20 and Figure 5.44 (See also Appendix 4). As two children (Child B and Child D) achieved age appropriate scores on the Understanding Paragraphs test, this may have affected the overall mean, which places the group within normal limits for this test in years 2 and 3. As these receptive assessments evaluate different aspects of comprehension, it was important to examine the overall differences between Word Classes (Receptive) and Understanding Paragraphs. A two by three repeated measures ANOVA was conducted on the data and no significant difference was found between the three data collection points and no significant interaction between years and tests;

F(1,4) = .951; *p*=.385. Using Cohen's (1988) conventions, this may be described as a medium large negative difference through to a large positive difference.

Table 5.20 ***Standard score descriptive statistics, mean differences and effect sizes for the receptive CELF-4UK subtests***

	Word Classes	Under Para	*R*	*Mean Diff*	*D*	*N*
Year 1	5.500 *SD(*2.345)	5.67 SD(3.204)	0.85	0.17 95% CI [-1.64, 1.98]	0.05 95% CI [-0.43, 0.54]	6
Year 2	5.33 *SD*(.817)	8.167 *SD*(3.544)	0.51	1.84 95% CI [-1.53, 5.20]	0.64 95%CI [-0.41, 1.69]	6
Year 3	6.000 *SD*(2.00)	7.000 *SD*(4.00)	0.63	1.00 95% CI [-2.93, 4.93]	0.27 95%CI [-0.59, 1.14]	*5
Mean over 3 Years	6.61 *SD*(3.58)	5.61 *SD*(1.52)	0.66	1.00 95% CI [-2.49, 4.50]	0.32 95%CI [-0.58, 1.21]	*5

equally weighted *SD*s, sample size adjusted and independent of sample *r*)

*Child E was unable to complete these assessments in the final year of the study due to a deterioriation in her hearing loss. Therefore only 5 children completed the tests.

SD=Standard Deviation *N*=Number *r*=correlation *d*=effect size
CI=confidence interval

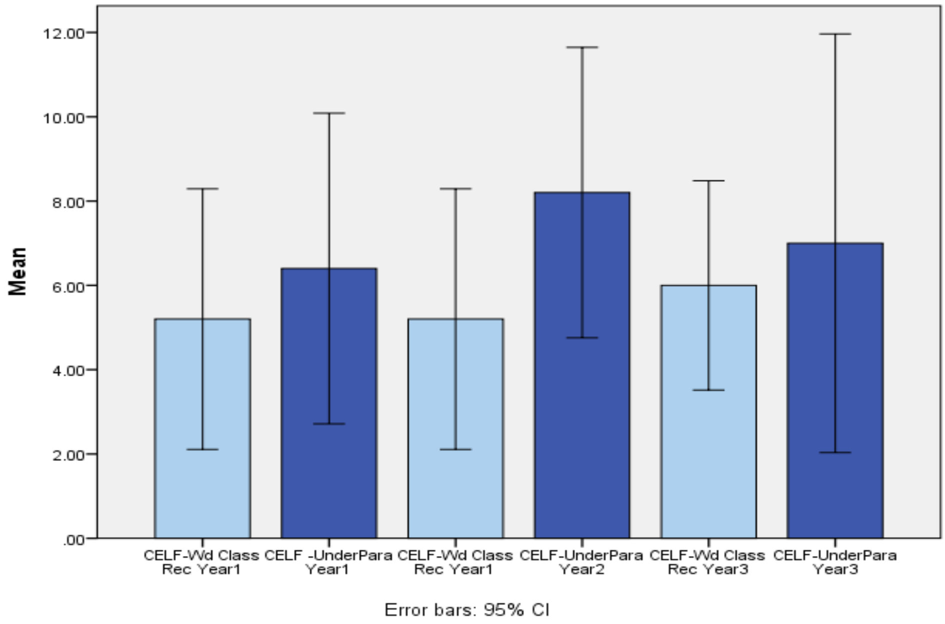

Figure 5.44 **Group mean standard scores for the receptive CELF-4UK subtests**

5.4.3 Expressive language results

Three subtests from the CELF-4UK were used in order to assess different abilities within expressive language. The Word Classes test is dependent upon the ability to understand word relationships. This is in contrast to the Recalling of Sentences task, which relies upon memory abilities, lexical development and syntactic knowledge. Finally, the Formulated Sentences test, evaluates the ability to generate appropriate grammatical and syntactic structures based upon a target word and picture. The means and standard deviations for the expressive tests are in Table 5.21 and Figure 5.45 (See also Appendix 5). In order to examine the overall differences between Word Classes (Expressive), Formulated Sentences and Recalling Sentences, a two by three ANOVA was conducted on the data over three years; $F(2,8) = 142.709$, $p=.001$. The post hoc (Bonferroni) test revealed a significant main effect for Word Classes (Expressive) versus Formulated Sentences and Sentence Recall regardless of the year. However, there was no significant effect for year and no significant interaction between year and tests.

Table 5.21 ***Standard score descriptive statistics for the expressive CELF-4UK subtests***

	Word Class Expressive	Recalling Sent	Formulating Sent	*N*
Year 1	5.000 *SD*(2.00)	1.400 *SD*(.894)	1.200 SD(.447)	6
Year 2	6.800 *SD*(1.304)	1.400 *SD*(.894)	1.200 SD(.447)	6
Year 3	7.200 *SD*(2.755)	1.600 *SD*(.894)	1.200 SD(.447)	5
Mean over 3 Years	6.33 *SD*(2.03)	1.47 SD(0.89)	1.200 SD(0.45)	5

*equally weighted *SD*s, sample size adjusted and independent of sample *r*)

**Child E was unable to complete these assessments in the final year of the study due to a deterioriation in her hearing loss. Therefore only 5 children completed the tests.

SD=Standard Deviation *N*=Number

Table 5.22 ***Comparison of the 3 year mean differences and effect sizes for the expressive language tests***

Test	***Mean & SD***	**Test**	***Mean & SD***	***r***	***Mean Diff***	***d***	***N***
Word Express (1)	6.33 *SD*(2.03)	**Recall Sent**	1.47 *SD*(0.89)	0.20	4.87 95% CI [1.25, 8.49]	2.69 95% CI [0.31, 5.08]	5
Word Express (2)	6.22 *SD*(2.03)	**Form Sent**	1.20 *SD*(0.45)	0.24	5.13 95% CI [1.64, 8.62]	3.02 95% CI [0.21, 5.84]	5
Recall Sent (3)	1.47 *SD*(0.89)	**Form Sent**	1.20 *SD*(0.45)	0.96	0.27 95% CI [-0.57, 1.11]	0.33 95% CI [-0.42, 1.08]	5

** *SD*=Standard Deviation *N*=Number *r*=correlation *d*=effect size CI=confidence interval

1 = The confidence interval indicating the pausible effect is within the range of a small/ medium positive difference through to a large positive difference

2 = The confidence interval indicating the pausible effect is within the range of a small positive difference through to a large positive difference

3= The confidence interval indicating the pausible effect is within the range of a small/medium negative difference through to a large positive difference

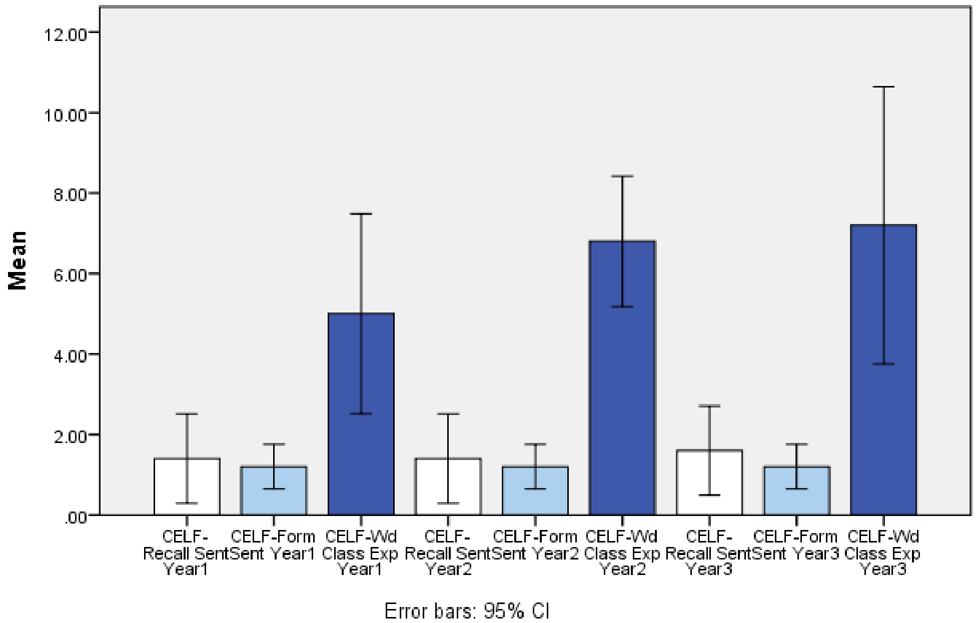

Figure 5.45 **Group mean standard scores for the expressive CELF-4UK subtests**

5.5 Group results for verbal and visual memory

Subtests from the WMTB-C and the AWMA were used to evaluate verbal and visual short-term memory and working memory.

5.5.1 Verbal short-term memory

The Non-word Recall, Word Recall and Digit Recall subtests were utilized to assess verbal short-term memory. The mean and standard deviations for verbal short-term memory tests are in Table 5.22 and Figure 5.46 (See Appendix 7). The participants performed considerably better on the Non-word Recall test than on the Word or Digit Recall Tests. In order to examine the overall differences between Non-word Recall and the other two tests of verbal short-term memory, a three by three repeated measures ANOVA was conducted to compare the scores on the three tests over the duration of the study; $F(2,10) = 23.049$, $p<.001$. The post hoc (Bonferroni) test revealed a significant main effect for Non-word Recall versus Word and Digit Recall regardless of the year. All six children in this study consistently recalled non-words better than words and digits. However, there was no significant effect for year and no significant interaction between year and tests. Three of the six children with LLD achieved scores within normal limits in Digit Recall (See Child A, B and E: Tables 5.3, 5.6 and 5.15).

Table 5.23 ***Standard score descriptive statistics for verbal short-term memory***

	Non-Word Recall	Word Recall	Digit Recall	*N*
Year 1	110.000 *SD*(10.658)	81.667 *SD*(12.485)	83.500 *SD* (16.380)	6
Year 2	110.167 *SD* 17.429)	84.000 *SD*(8.786)	86.667 *SD*(13.366)	6
Year 3	112.833 *SD*(8.864)	72.500 *SD* 4.728)	80.167 *SD*(13.703)	6
Mean over 3 Years	111.00 *SD*(12.32)	79.39 *SD*(8.67)	83.45 *SD*(14.48)	6

SD=Standard Deviation *N* = Number

Table 5.24 ***Comparison of the 3 year mean differences and effect sizes for the verbal short-term memory tests***

Test	Mean & *SD*	Test	Mean & *SD*	*r*	*Mean Diff*	*d*	*N*
Non-word (1)	111.00 *SD* (12.32)	**Word Recall**	79.39 *SD*(8.67)	.08	31.61 95% CI [10.75,52.47]	2.65 95% CI [0.67,4.64]	6
Non-word (2)	111.00 *SD* (12.32)	**Digit Recall**	83.45 *SD*(14.48)	.26	26.55 95% CI [2.96, 50.15]	1.77 95% CI [0.24, 3.29]	6
Word Recall (3)	79.39 *SD*(8.67)	**Digit Recall**	83.45 *SD*(14.48)	.33	-5.06 95% CI [-25.46, 15.45]	-.038 95% CI [-1.54, .78]	6

*equally weighted *SD*s, sample size adjusted and independent of sample *r*

SD=Standard Deviation *N*=Number *r*=correlation *d*=effect size

CI=confidence interval

1 = The confidence interval indicating the pausible effect is within the range of a medium/large positive difference through to a large positive difference

2 = The confidence interval indicating the pausible effect is within the range of a small positive difference through to a large positive difference

3= The confidence interval indicating the pausible effect is within a very large negative difference through to a large positive difference

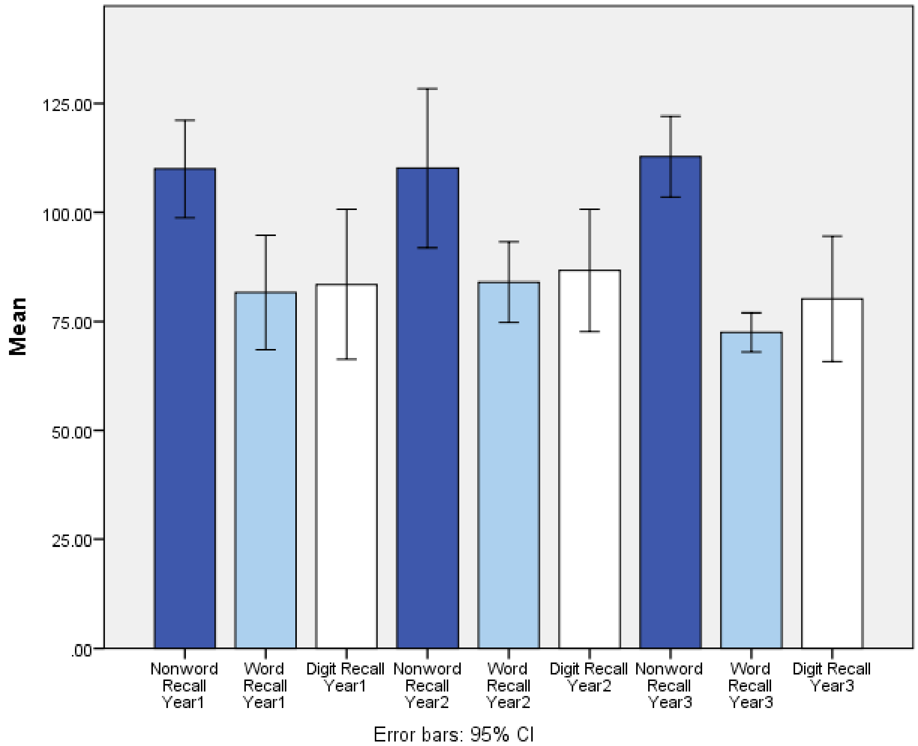

Figure 5.46 **Group mean standard scores for verbal short-term memory**

5.5.2 Verbal working memory

Backward Digit and Listening Recall tests from the WMTB-C evaluated verbal working memory. As these tests differ in the amount of demand placed upon semantic and lexical knowledge, as well as access to the long term memory, it is important to compare their results. The mean scores and standard deviations for the group are in Table 5.24 and Figure 5.47 (See Appendix 8). In order to examine the overall differences between Backward Digit Recall and Listening Recall, a two by three ANOVA was conducted on the data: $F(1,5) = 1.186$, $p=.326$. No significant difference was found between tests or years. Using Cohen's (1988) conventions, this may be described as a medium/large negative difference through to a large positive difference. When examining the results further, it became apparent that five out of six children achieved age appropriate scores in Backward

Digit Recall, but only two out of six in the Listening Recall task (Child A and Child E). They also exhibited average ability in Digit Recall. Child D displayed standard scores below 85 on both the Backward Digit Recall and Listening Recall test at both the first and second point of testing. In the final year of the study, he achieved a standard score of 90 on the Listening Recall task (See Table 5.12).

Table 5.25 ***Standard score descriptive statistics, mean differences and effect sizes for verbal working memory***

	Listening Recall	Backward Digit	*R*	*Mean Diff*	*D*	*N*
Year 1	77.00 *SD*(11.08)	87.00 *SD*(8.88)	0.10	10.00 95% CI [-4.14, 24.14]	0.89 95% CI [-0.24, 2.02]	6
Year 2	79.17 *SD*(17.77)	88.83 *SD*(17.19)	0.56	9.66 95% CI [-7.48, 26.80]	0.49 95% CI [-0.28, 1.27]	6
Year 3	84.83 *SD* (24.14)	88.67 *SD*(14.87)	0.05	3.84 95% CI [-25.30, 32.98]	0.17 95% CI [-0.92, 1.26]	6
Mean over 3 Years	80.33 *SD* (17.37)	88.17 *SD*(13.65)	0.24	7.83 95% CI [-12.51, 28.17]	0.45 95% CI [-0.55, 1.44]	6

*equally weighted *SD*s, sample size adjusted and independent of sample *r*

SD=Standard Deviation *N*=Number *r*=correlation *d*=effect size

CI=confidence interval

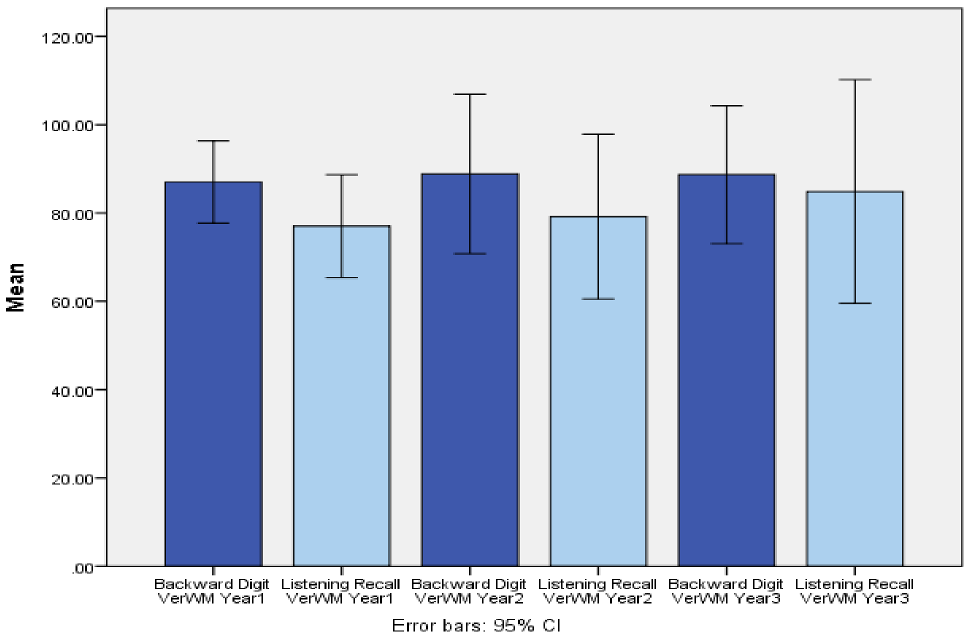

Figure 5.47 **Group mean standard scores for verbal working memory**

5.5.3 Visual short-term memory and working memory results

The Block Recall test from the WMTB-C assessed visual short-term memory while the Odd One Out test from the AWMA evaluated visual working memory. The comparison of these tests addresses whether there is a difference between visual short-term memory and working memory, as well as enabling further examination of central executive functioning. The descriptive statistics are displayed in Table 5.24 and Figure 5.48 (See Appendix 9). A two by three repeated measures ANOVA conducted to compare the standard scores of the AWMA and the Block Recall test over the three years; $F(1,4) = 17.769$, $p=.014$. The results revealed that there was a significant main effect between the two tests. However, there was no significant effect for year and no significant interaction between year and tests. Children performed better on the AWMA than the Block Recall test regardless of the year. While both test scores are considered to be within the age appropriate range, the AWMA scores are much higher. This may be due to the interactive nature of the assessment, which was administered via a computer, as children may find this more engaging. Using Cohen's (1988) conventions, this may be described as a small negative effect through to a large positive difference.

Table 5.26 ***Standard score descriptive statistics, mean differences and effect sizes for visual short-term memory and working memory***

	AWMA	Block Recall	*R*	*Mean Diff*	*d*	*N*
Year 1	112.000 *SD*(6.228)	97.333 *SD*(14.038)	0.61	14.67 95% CI [2.73, 26.61]	1.21 95% CI [0.14, 2.28]	6
Year 2	118.000 *SD*(10.449)	106.667 *SD*(13.764)	0.71	11.33 95% CI [1.17, 21.50]	0.83 95% CI [0.06,1.60]	6
Year 3	120.100 *SD*(7.219)	106.833 *SD*(18.633)	0.21	13.27 95% CI [-9.74, 36.27]	0.81 95% CI [-0.41, 2.03]	5
Mean over 3 Years	116.70 *SD* (7.97)	103.61 *SD*(15.48)	0.51	13.06 95% CI [-3.47, 29.59]	0.92 95% CI [-0.15, 1.99]	5

*equally weighted *SD*s, sample size adjusted and independent of sample *r*)

**Child B was unable to complete the AWMA assessment in the final year of the study due to a fault with the computer, as well as time constraints with examinations.

SD=Standard Deviation *N*=Number *r*=correlation *d*=effect size
CI=confidence interval

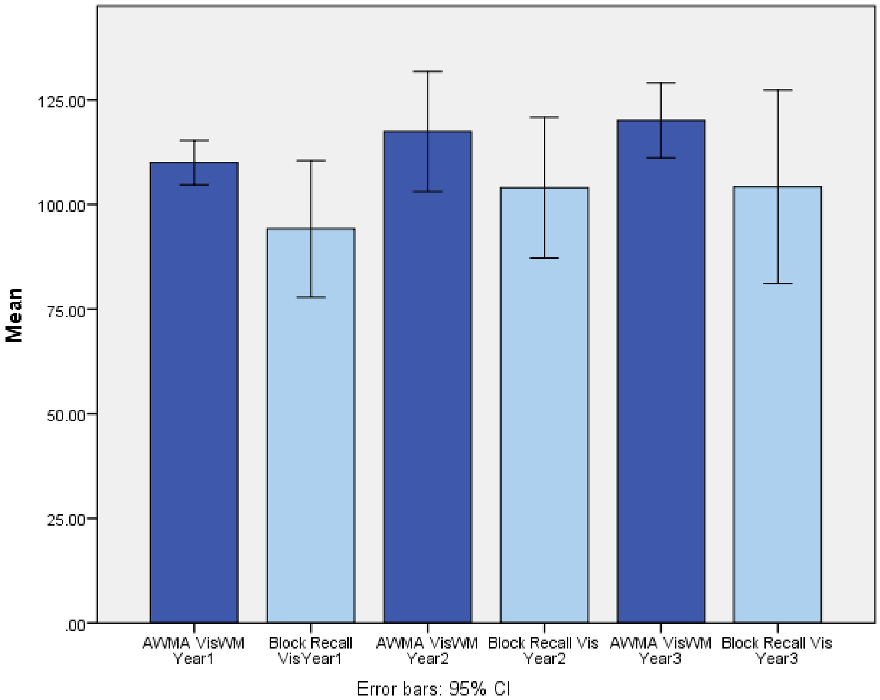

Figure 5.48 **Group mean standard scores for visual short-term memory and working memory**

5.6 Group results for the Informal Memory Test

The Informal Memory Test was used to investigate if children performed similarly in both a verbal and a visual working memory task that relied heavily upon word knowledge and access to the long term memory. All six children in this study had higher scores on the visual portion of the test than the verbal part. The mean and standard deviations for these tasks are in Table 5.27 and Figure 5.49. There is a clear pattern of considerable difference between their verbal and visual scores at all three data collection points, p=.008 (See Table 5.28).

Table 5.27 Raw score means and standard deviations for Informal Memory Test for children with hearing impairment and *LLD*

	Mean	*SD*	*N*
Informal Memory Test Verbal Year 1	15.500	4.679	6
Informal Memory Test Visual Year 1	18.667	3.165	6
Informal Memory Test Verbal Year 2	16.00	3.286	6
Informal Memory Test Visual Year 2	21.000	2.190	6
Informal Memory Test Verbal Year 3	16.600	1.516	*5
Informal Memory Test Visual Year 3	21.600	1.5167	*5

*Child B was unable to complete the IMT assessment in the final year of the study as a result of time constraints, due to examinations.

SD=Standard Deviation *N*=Number

Table 5.28 *Informal Memory Test verbal and visual task t-tests*

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Informal Memory Test Verbal Year1 - Informal Memory Test Visual Year1	-3.16667	1.83485	.74907	-5.09222	-1.24111	-4.227	5	.008
Pair 2	Informal Memory Test Verbal Year2 - Informal Memory Test Visual Year 2	-5.00000	1.41421	.57735	-6.48413	-3.51587	-8.660	5	.000
Pair 3	Informal Memory Test Verbal Year3 - Informal Memory Test Visual Year 3	-5.00000	1.00000	.44721	-6.24166	-3.75834	-11.180	4	.000

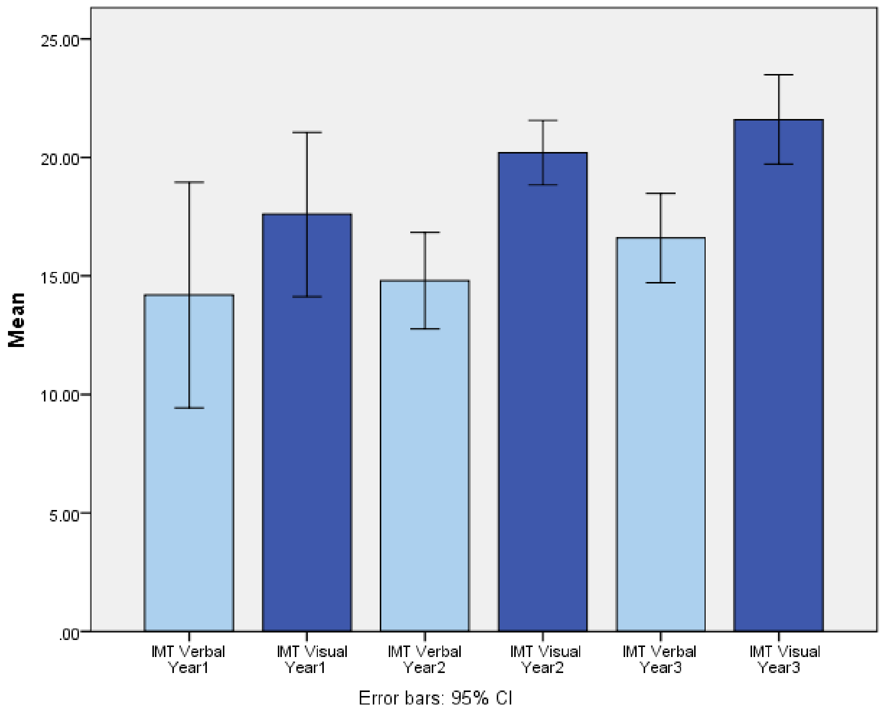

Figure 5.49 **Group mean raw scores for children with hearing impairment on the Informal Memory Test (IMT)**

Their scores are compared to the normally hearing school age children in Table 5.29, which demonstrate that the normally hearing children performed equally well on both tasks, while the children with hearing impairment and LLD performed better on the visual task.

Table 5.29 ***Comparison of mean raw scores on the Informal Memory Test***

	Verbal Task	Visual Task
School Age Children	20.675	20.300
Children with Hearing Impairment	*16.030	*20.222

*Mean score for the 3 years

5.7 Memory Profile

The mean standard scores for both verbal and visual memory tests from the WMTB-C and AWMA over the duration of the study for this cohort of children with hearing impairment are exhibited in Figure 5.50. These results combine to create a profile of their memory abilities, which define their strengths and weaknesses as a group. The children with hearing impairment exhibit strengths in visual memory, but weakness in verbal short-term memory. The children's memory profile is considerably different from other populations of children with developmental disorders. These differences will be discussed in Chapter 6, Section 6.6.

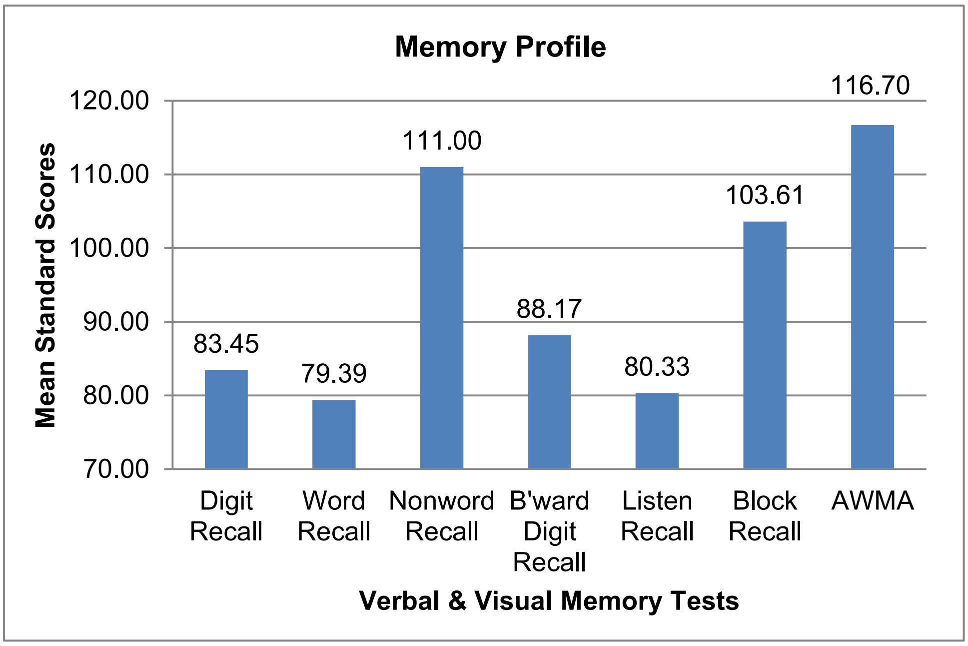

Figure 5.50 **Memory profile for the group of children with hearing impairment**

5.8 Summary

In this chapter, the vocabulary, language and memory abilities for the children with hearing impairment were examined annually on three occasions. This process enabled the evaluation of possible changes and the identification of patterns of development in vocabulary acquisition, language and memory. The children exhibited higher scores in expressive vocabulary than receptive vocabulary. The children with hearing impairment and LLD showed the weakest abilities in Sentence Formulation and Recalling of Sentences, performing more than two standard deviations below the mean. The children exhibited strengths in visual short-term memory and working memory, but weakness in verbal short-term memory particularly Word Recall. Chapter 6 will discuss these findings and their implications both within and across individuals in relation to the current body of knowledge in the field of hearing impairment and their clinical implications.

Chapter 6 Discussion

6.1 Introduction

Chapter 6 begins with a restatement of the main aim and objectives of the research study. The second part of the chapter discusses the findings of the study with reference to the literature regarding vocabulary, language and memory abilities in children with hearing impairment. The third section of this chapter explores the limitations of the study. The fourth part of the chapter identifies the clinical implications of the research findings. The final section of Chapter 6 considers ways in which these findings can be applied clinically in a therapeutic context.

6.2 Research question, aim and objectives

One of the foci of the research in the field of paediatric hearing impairment is the large variability in spoken language outcomes for orally educated children. The overarching research question from the current study: “What is the developmental profile and trajectory in vocabulary, language and memory for children with hearing impairment who exhibit language learning difficulties” was generated from this debate. The aim of the study was to investigate factors associated with successful vocabulary and language development in this cohort of children.

This study addressed the above research question and aim by targeting a small subgroup of this population of children who despite relatively early diagnosis and fitting, long-term use, parental support and intensive educational input, have not achieved age appropriate spoken language abilities. The objectives of the research study were:

1. To profile memory, vocabulary and language development within a longitudinal study
2. To investigate what aspects of vocabulary, language and memory are impacting upon the development of these children
3. To develop a research and theory-driven intervention to pilot test the findings of the study

Objective 3 is addressed in Chapter 7. The current chapter discusses the results are related to objectives 1 and 2.

6.3 Vocabulary and language development

6.3.1 Pattern of vocabulary development

The children with hearing impairment in the present study, like an identified minority of children in the studies by Geers and Nicholas (2013), Nicholas and Geers (2013) and Sarant et al. (2009), remained severely delayed in both receptive and expressive vocabulary in relation to their normally hearing peers (See Chapter 5, Section 5.4.1). Their standard scores on both tests were between one (i.e. < 85) and two standard deviations (i.e. <70) below the mean throughout the duration of the study. The present study found that the children with hearing impairment and additional language learning difficulties achieved higher standard scores on expressive vocabulary than receptive vocabulary and a significant difference was found between them (See Chapter 5, Table 5.19 and Figure 5.43). The results demonstrate that this particular group of children with hearing impairment and additional LLD do not seem to display a different pattern of vocabulary development from other children with hearing impairment. They instead, appear to develop vocabulary much more slowly than other children with hearing impairment who follow a more typical pattern of language development. In brief, they have poor vocabulary, which impacts on wider language skills, but in itself appears to be caused by verbal short-term memory impairments, with particular reference to the ability to store and access words from their long term memory.

The children with LLD in the current study continue to exhibit both substantial and enduring difficulties in the development of age appropriate receptive and expressive vocabulary. The ramifications of these difficulties in the long term appear to have contributed to their poor expressive and receptive language development, as well as word-finding difficulties, which were apparent during the administration of the EVT-2. In many cases when the participants were unable to name the target pictures in the assessment, they would describe the attributes of the object or use a gesture depicting the function of it. The children often stated where they had learned the word or how it was familiar to them and utilized phrases like “I know what it is but just can’t remember the name.” Thus, they may have had the concept, but lacked the ability to access the word from the long term memory.

As identified in Chapter 2, Section 2.5, researchers have found that some children with hearing impairment acquire vocabulary more slowly than their normally hearing peers, but a large proportion can develop age appropriate vocabulary by the age of 4;6 and many others by the age of 10;6 (Chilosi et al., 2013; Hayes et al., 2009; Moeller et al., 2007b; Nicholas and Geers, 2006; Nicholas and Geers, 2007). Other researchers in the field of hearing impairment have also found that expressive vocabulary development is in advance of receptive vocabulary development. This pattern of vocabulary acquisition in orally educated children with hearing impairment is exhibited both in children fitted with hearing aids or cochlear implants under the age of 1;6 years or by 4;6 years (Caselli et al., 2012; Chilosi et al., 2013; Geers et al., 2009; Geers and Nicholas, 2013; Nicholas and Geers, 2013). Researchers have also found that expressive vocabulary remains more advanced in its development than receptive vocabulary in older children with hearing impairment (Geers and Nicholas, 2013).

Moeller et al. (2007b) investigated the development of vocabulary longitudinally in normally hearing children and children with hearing impairment, aged between 10 and 30 months of age. They identified a subgroup of toddlers who exhibited a similar pattern of extremely delayed vocabulary development as the children in the current study (See Chapter 2, Section 2.6.2.). There is no further published research by Moeller et al. which provides data on whether this group of young children “at risk” of poor development did indeed continue to have difficulties in the acquisition of vocabulary and spoken language in the long-term.

6.3.2 Pattern of language development

The age range of the children at the beginning of the current research study was between 8;5 and 13;10. Despite their very different ages, patterns of language development for each child are similar. The children acquired expressive vocabulary more quickly than receptive vocabulary, but morphosyntactic abilities continued to remain significantly delayed (See Chapter 5, Section 5.4). The general pattern of development exhibited in this case series has been mirrored by other researchers who also found that syntax and grammar develop at a slower rate than receptive and expressive vocabulary and these certain aspects of language are more reliant on early auditory experience than others (Caselli et al., 2012; Duchesne et al., 2009; Geers et al., 2009; Geers and Nicholas, 2013; Harris et al., 2013; Nicholas and Geers, 2006; Nicholas and Geers, 2013; Niparko et al., 2010; Sarant et al., 2009; Tomblin et al., 2015). However, the children with hearing impairment and LLD in the current study exhibit significantly poorer scores across all areas of receptive and expressive language than those reported in most other studies.

6.3.2.1 Receptive language

The children in the case series remained substantially delayed (i.e. more than 1 standard deviation below the mean) in their receptive language regardless of their chronological age. As a group, there was no significant difference found between the results of the Understanding of Paragraphs and Word Classes (Receptive) (See Table 5.20 and Figure 5.44). Only one child (Child B) consistently achieved age appropriate scores on the Understanding Paragraphs subtest for the duration of the study (i.e. standard scores: 11,13 and 14). Perhaps this was due to her longer experience of language learning (i.e. chronological age 13;10 years at the inception of the study), as well as increased experience of the didactic style of teaching that teenagers receive as they reach the later stages of secondary school. This additional experience may have benefitted her in the Understanding Paragraphs subtest, although this is not possible to demonstrate with the current data. It is suggested that competency on the Understanding Paragraph task relies on comprehension of vocabulary, and syntactic and semantic cues which can be easily missed by some children with hearing impairment, especially in the context of their limited knowledge of semantics, and poorer morphosyntactic abilities. For example, "<u>She</u> is coming" versus "H<u>e</u> is coming." "Some are needed" versus "One is needed" "Get <u>my</u> bag." versus "Get <u>the</u> bag."

The case series study's findings are similar to those of other researchers who also found that regardless of age of fitting and oral education, the language delays in some children continue to persist over time. For example, Geers and Nicholas

(2013) found receptive language scores were more than one standard deviation below the mean for 55% of their young cochlear implant users at age 4;6 though this proportion reduced to 48% by the age of 10;6. However, the participants in the present study exhibited standard scores both in receptive and expressive language that were significantly poorer than those in the Geers and Nicholas (2013) study (See Chapter 2, Section 2.7.1 and Table 2.4 for a summary). The children with LLD achieved mean group scores over the course of the study ranging from 5.2 to 6.0 for the Word Classes (Receptive) subtest and 6.4 to 8.2 for Understanding Paragraphs (Standard scores below 7 are more than one standard deviation below the mean) (See Chapter 5, Section 5.4.2 and Table 5.20). The current study's findings suggest that the long-term deficits in vocabulary development alongside their difficulties in accessing their long term memory and verbal short-term memory difficulties have negatively affected these children's ability to comprehend and recall the content of paragraphs when read aloud.

6.3.2.2 Expressive Language

There were notable differences between the results in the three measures of expressive language from the CELF-4UK for the case series of children. These children with LLD performed significantly better in the Word Classes (Expressive) subtest (mean standard scores between 5.0 and 7.2) than the Formulated Sentences (mean standard score of 1.2) or Recalling Sentences tasks (mean standard scores between 1.4 and 1.6) (See Chapter 5, Tables 5.21 and 5.22 and Figure 5.45).

The Word Classes task asks the child to explain "Why" two words relate to one another. It does not rely on the child generating correct grammar and syntactical structures, which other researchers have found to be areas of weakness (Boons et al., 2012; Caselli et al., 2012; Duchesne et al., 2009; Geers and Nicholas, 2013; Nittrouer et al., 2014; Szagun, 2001). These difficulties in part may be due to the children's limited vocabulary and perceptual problems, as some grammatical morphemes (i.e. plural or possessive "s") and articles (i.e. "a" "an") are unstressed and have limited acoustic information. These findings in the field of hearing impairment suggest that therapeutic input should continue to focus on morphosyntactic development throughout the primary years, as these areas are vulnerable to delayed development in some children with hearing impairment.

The Recalling Sentences subtest assesses a child’s ability to reproduce correctly a target sentence exactly as it was spoken to them. This task relies on verbal short-term memory abilities, linguistic knowledge, and higher-level language abilities. All six children with hearing impairment and LLD performed more than two standard deviations below the mean on this subtest (i.e. mean standard scores of 1.4 to 1.6) (See Chapter 5, Section 5.4.3 and Table 5.21). Their extremely low scores on this test are indicative of their difficulties in verbal short-term memory, in particular word recall and access to the lexicon. Geers and Nicholas (2013) found the performance of the children in their study on Recalling Sentences subtest was the weakest of all the expressive CELF-4 subtests; however their participant’s scores were still within one standard deviation with a standard score of 7.47. It is important to bear in mind that the Sentence Recall task relies heavily on both language and memory abilities and that poor functioning on these tests may indeed be reflecting deficits in vocabulary, semantic knowledge, verbal short-term memory and poor lexical access that these children with LLD display. The children in the current study were unable to recall the sentences verbatim, but were able to reproduce the content of the target sentences. The ability to comprehend “the message” but forget the exact words and/or word order is a compensatory strategy for managing information in the context of limited memory and/or processing abilities. This has been observed by other researchers investigating language development in normally hearing children (e.g. Alloway and Gathercole, 2005; Marshall and Nation, 2003).

The results from the Formulated Sentences test were the poorest of all language measures for the children with LLD, with the mean standard score being 1.2. All six of the children with hearing impairment and LLD struggled to generate sentences (using key words) that were correct in content, syntax and grammar (See Chapter 5, Section 5.4.3). These results are considerably different from those of Geers and Nicholas (2013) who found their sample demonstrated a mean standard score of 9.85. These findings demonstrate that the case series of children with LLD exhibit a more delayed pattern of expressive language development than their more typically developing peers with hearing impairment. These findings suggest that the substantial delays in the early stages of language development have a negative impact upon the acquisition of morphosyntactic skills, and that these difficulties appear to persist despite on-going educational support and therapeutic input.

6.3.3 Catching up with their normally hearing peers?

Vocabulary

The children in the current study continued to display exceptionally low standard scores: at least 2 standard deviations below the mean on the BPVS 2, and as a group were unable maintain receptive vocabulary levels over the course of the study. That is to say, they did not maintain their same standard score in relation to their chronological age year on year. The highest standard scores achieved by any child in the group was 71. Even the oldest of the participants (Child B) at age 15;9 did not show any improvement in receptive vocabulary development by the end of the study, as she remained more than 2 standard deviations below the mean (See Chapter 5, Table 5.4). However, the children in the current study did maintain their level of expressive vocabulary development in comparison to their peers, in that their standard scores did not alter considerably over the duration of the study. All six children did show an improvement in their raw scores in expressive vocabulary year on year. However, none of them achieved age appropriate standard scores in expressive vocabulary with the exception of Child E (See Chapter 5, Table 5.13). She achieved a standard score of 92, at the chronological age of 11;11 years by the final year of the study. Two other children (Child A and Child F) exhibited a small improvement in their standard scores for expressive vocabulary over the course of the study, but remained more than 1 standard deviation below the mean (See Chapter 5, Table 5.1 and Table 5.16).

The results of the current study are in contrast to Geers and Nicholas (2013) in their follow up study which investigated if receptive and expressive vocabulary abilities were maintained or indeed improved. The majority of the children in that study (i.e. 44 out of a total of 47 children) were able to maintain or improve their standard scores and remain within normal limits at the age of 10;6. In the case of the 23 children who at the age of 4;6 displayed standard scores below 85, 11 of these children improved their scores to be within the typically developing range for their chronological age by 10;6. The current case series findings can be viewed in the wider context of other researchers who also found that between 20% and 30% of children who receive their cochlear implant by the age of 2;6 did not achieve age appropriate receptive and expressive vocabulary by the age of 4;6 or 10;6 (Geers et al., 2009; Hayes et al., 2009; Nicholas and Geers, 2006; Nicholas and Geers, 2007; Nicholas and Geers, 2013; Pisoni et al., 2011). These results are drawn into sharper focus when compared with Pisoni et al. (2011) who found that 82% of their teenage participants achieved age appropriate receptive vocabulary abilities by adolescence. This finding was irrespective of their age of fitting of their cochlear implant. These findings differentiate the children in the case series from the majority of other children with hearing impairment in that, if given enough time and appropriate input, many children with hearing impairment do achieve age appropriate receptive and expressive vocabulary. Thus there must be additional issues involved in the deficits exhibited by children with LLD in the current study.

Language

As a group, the children in the current study continued to display exceptionally delayed receptive and expressive language and did not show any improvement in their standard scores in either the Recalling Sentences or the Formulated Sentences subtests. Their standard scores remained between 1 and 3 (i.e. 0.1 to 1 percentile) throughout the study. Sentence Recall tasks require the verbatim recall of individual words, as well as syntactic structures. Given that the children with hearing impairment and LLD have considerable difficulties in word recall (i.e. verbal short-term memory) and weaknesses in grammatical and syntactic knowledge, it is not surprising that they have significant difficulties with both of these tasks. However, with regard to the Word Classes (Receptive) and Word Classes (Expressive), which evaluate word knowledge, two out of six participants (Receptive subtest) and three of out of six participants (Expressive subtest) showed an improvement in their standard scores. Child A, B and F attained standard scores within one standard deviation between 7 and 11 (See Chapter 5, Table 5.1, Table 5.4 and Table 5.11). The language results for the current study mirror those of Geers and Nicholas (2013) who found that 27% of the children fitted with their equipment under the age of 18 months did not achieve age appropriate language by the age of 10;6 (See Chapter 2, Section 2.7.1 and Table 2.4). The implications of the findings from Geers and Nicholas (2013) unveil the fact that despite early auditory experience and therapeutic input, a proportion of children with hearing impairment will not achieve language abilities commensurate to that of their peers. The findings from the current study provide the initial answers as to the language profile that this subgroup of children with hearing impairment exhibit after several years of device use.

Considerable delays in all aspects of language development

As has been shown, the children in the current study exhibit considerable deficits in receptive and expressive vocabulary and language (See Chapter 5, Section 5.4). The study found that changes to receptive and expressive language standard scores were minimal and that the difficulties in vocabulary and morphosyntactic abilities persist into adolescence. Hawker et al. (2008) also investigated the long-term language outcomes in children with hearing impairment between the ages of 10;6 and 14;6 who were educated either orally or through total communication (See Chapter 2, Section 2.8). Their study compared six children with hearing impairment to a control group of other children with hearing impairment matched on age, communication mode and duration of cochlear implant use. They found that the children in both groups displayed poor language development. However, the study group displayed disproportionately lower scores than the control group. It is difficult to directly compare the findings by Hawker et al. (2008) with the current study, as their population of children with hearing impairments was considerably different from the current research study. The children in the current study children had access to sound via hearing aids or a cochlear implant by the age of 2;6 years and were orally educated. However, their findings in relation to the extremely poor development in all areas of language parallel those of the current study despite the different communication modes and later fitting of the cochlear implants.

6.3.4 Summary of findings in relation to the research

Researchers in general in hearing impairment have discovered that vocabulary develops more easily than other aspects of language such as grammar and syntax (Caselli et al., 2012; Duchesne et al., 2009; Geers et al., 2009; Geers and Nicholas, 2013; Nicholas and Geers, 2013). They have also have found that children who are fitted earlier with their hearing aids or cochlear implant achieve better speech and language outcomes than later fitted children (Niparko et al., 2010; Peterson et al., 2010). The findings from the current study mirror those of Nicholas and Geers (2013) who evaluated the receptive and expressive language abilities of children who were fitted with their cochlear implant under the age of 18 months. They found that 31% of their study population did not achieve age appropriate scores by the age of 4;6. Several other researchers have also observed these findings. That is to say, that even in the context of early access to sound and speech as the primary mode of communication, approximately 20 to 30 percent of children with hearing impairment did not achieve receptive and expressive language levels similar to their normally hearing peers by the age of 4;6 (Duchesne et al., 2009; Geers and Nicholas, 2013; Nicholas and Geers, 2006; Nicholas and Geers, 2013; Sarant et al., 2009) or by the end of primary school (e.g. age 10;6-11;0) (Geers and Nicholas, 2013; Geers and Sedey, 2010; Pisoni and Cleary, 2003).

The participant characteristics of the children in the current study are similar to many children with hearing impairment in the UK (i.e. consistent hearing aid/cochlear implant user, device fitting under age of 2;6, oral education, parental support) which should have allowed them to achieve age appropriate spoken language by the time they reached primary school. Despite their relatively early experience of auditory input and intensive support from their family and support services, the children in the case series did not develop expressive and receptive language abilities equal to that of their normally hearing peers by the time they have reached primary or even secondary school. It is postulated that the children’s deficits in vocabulary and semantic knowledge alongside difficulties in lexical access and verbal short-term memory, in particular Word Recall, may be the additional factors that need to be considered in relation to why they exhibit such disproportionate difficulties in the acquisition of spoken language. This will be discussed in detail in Section 6.5.

In summary, the findings from the current research study provide greater insight into the long-term language learning difficulties that a subgroup of children with hearing impairment experience. The longitudinal nature of the study, as well as the cross section of ages, indicate that these patterns of deficits in language are not related to a chronological age or developmental stage, but are a persistent feature of language development for these and almost certainly a small but important proportion of other children with hearing impairment. Their pattern of vocabulary and language development, in conjunction with results from memory assessments, may illuminate ways in which to manage better their clinical and educational needs.

6.4 Clinical implications of vocabulary findings

The current study's findings identify that this subgroup of children with hearing impairment continue to exhibit substantial delays in vocabulary and language abilities in relation to both their normally hearing peers and peers with hearing impairment. All of the children in the study had a history of difficulties in early word learning and combining words. These difficulties manifested themselves in extremely delayed expressive and receptive vocabulary and language abilities. While these participants appear to follow a similar sequence in vocabulary acquisition to other children with hearing impairment, they exhibit considerably poorer standard scores. As vocabulary has been found to develop more easily than other areas of language and appears to "catch up" first in children with hearing impairment, this finding is of considerable concern. The delay in vocabulary acquisition reduces a child's ability to build other aspects of language skill, such as semantics and syntax. The slow acquisition of vocabulary in the early stages of language development may indeed be an indicator of a child with hearing impairment who is at risk of delayed or atypical development, and therefore may not acquire vocabulary and language equal to that of their normally hearing peers by the age of formal school entry (i.e. 4;6 years). One way in which to address these difficulties may be by therapeutically targeting word learning and vocabulary acquisition when children with hearing impairment are very young.

This may enhance their vocabulary development and thus their language acquisition. A proposed therapeutic programme will be addressed in more detail in Section 6.9, Application to clinical practice.

6.5 Verbal and visual short-term memory and working memory abilities

6.5.1 Verbal short-term memory

Historically, Digit Recall and multisyllabic Non-word Recall tests have been utilized to assess verbal short-term memory in children with hearing impairment (See Chapter 3, Sections 3.6, 3.6.1 and 3.6.2 and Table 3.2 for a review). Many researchers have found that children with hearing impairment are poorer at recalling multisyllabic non-words than their normally hearing peers (Dawson et al., 2002; Diller, 2010; Harris et al., 2013; Lina-Granade et al., 2010; Pisoni et al., 2011; Pisoni and Cleary, 2003; Wass et al., 2010; Willstedt-Svensson et al., 2004) and demonstrate below average abilities in Digit Recall even after several years of device use (Harris et al., 2013; Pisoni et al., 2011). Nonetheless, many of these children still exhibit age appropriate language. Even in the presence of age appropriate digit recall abilities, children can still display considerable vocabulary and language delays and vice versa (Freed et al., 2012; Vance, 2008). That is to say, there is no causal link in either direction between language impairment and poor verbal short-term memory abilities as identified by Digit Recall or traditional non-Word Recall tests (See Chapter 3, Section 3.4.1). In this context, the use of other verbal short-term memory tests alongside Digit Recall may illuminate further weaknesses that would otherwise remain hidden.

The current research utilized single syllable Non-word Recall, single syllable Word Recall and Digit Recall tasks to evaluate verbal short-term memory (See Chapter 3, Section 3.4.1. for a discussion of Word Recall as a measure of short-term memory). It appears to be the first time this approach has been used in the field of paediatric hearing impairment. The current study group of children achieved age appropriate standard scores in Non-word Recall test, but scored at least one standard deviation below the mean in Word Recall. All six children performed considerably better on the Non-word Recall task than the Word Recall and Digit Recall tasks (See Chapter 5, Section 5.5.1, and Tables 5.23 and 5.24). These Non-word Recall findings differ from those of previous researchers who utilized multi-syllabic Non-word Recall tests and found that children with hearing impairment were poorer at multisyllabic Non-word Recall than their normally hearing peers (Dawson et al., 2002; Diller, 2010; Harris et al., 2013; Lina-Granade et al., 2010; Pisoni et al., 2011; Pisoni and Cleary, 2003; Wass et al., 2010; Willstedt-Svensson et al., 2004). The Word Recall findings from the current study differ from those of Wass et al. (2010) and Diller (2010) who found that children with hearing impairment performed better when recalling real words than multi-syllabic non-words. The use of a different battery of memory assessments in the current study has accounted for these unique findings.

The current research findings with regard to Non-word Recall and Word Recall are unusual, in that normally hearing children recall "real" words better than non-words (Baddeley, 2003; Gathercole et al., 1999; Turner et al., 2000). The target tasks for both conditions (real and non-words) were the same (i.e. single syllable and CVC), which is different from previous researchers who utilized multisyllabic words that increase in syllable length. The children with hearing impairment and LLD achieved age-appropriate scores on the Non-word Recall test. Perhaps this is due to the task requiring only limited access to long term memory and the lexicon. The children in the current study consistently achieve scores more than one standard below the mean (mean score 79.39) on the Word Recall task over the duration of the study (See Chapter 5, Section 5.5.1, Tables 5.23 and 5.24 and Figure 5.46). The study's findings in relation to Word Recall and Digit Recall provide support for the assertion that the children with hearing impairment have poor quality or less defined phonological and lexical representations, as well as poor lexical organization. These deficits place additional demands upon long term memory and make storage and retrieval processes less efficient (Mainela-Arnold and Evans, 2005). In practice, this means that the children with hearing impairment are less able to recall and/or retain target words and that the words are forgotten (i.e. decayed) before the children are able to recall them. It is likely that these children with hearing impairment would benefit from visual support, as a way in which to decrease demands upon verbal short-term memory and long term memory.

In the context of the current research findings, the following computer analogy is useful in the explanation of the interaction between verbal short-term memory and long term memory. The words in a child's long term memory are akin to documents on the "desktop." If there are fifty files poorly organized (e.g. not organized alphabetically or according to topic) with a variety of names that are unclear, then trying to access the documents would demand more effort and time. For the children in the current study, their ability to access the appropriate documents from the desktop is influenced by the poor organization of the documents and the incomplete names of the word documents. In practice this meant that documents (i.e. words) could not be located on the desktop (i.e. long term memory) before the names are forgotten.

Nittrouer et al. (2013) found that the children with hearing impairment in their study also had difficulties with the storage of words, but not with processing (see Chapter 3, Section 3.7.2). That is to say that their results showed that deficits were apparent in verbal short-term memory, but not verbal working memory. The poor ability to recall "real" words may be a diagnostic indicator of a child who will have difficulties in storing new vocabulary items and thus exhibit delayed vocabulary development. The current study group had considerable difficulties in learning and retaining new vocabulary items, as well as combining them into multi-word utterances. They continue to display exceptionally poor levels of vocabulary in relation to their normally hearing peers. The therapeutic implications are discussed in detail in Section 6.9, Application to clinical practice.

6.5.2 Verbal working memory

Verbal working memory tests evaluate a child's ability to temporarily store information and process it. The Backward Digit Recall task and Listening Recall task were utilized in the present study to evaluate verbal working memory. As a group the children with LLD achieved age appropriate scores (i.e. standard scores of 87 or 88) on the Backward Digit Recall task, but below average scores in the Listening Recall task (i.e. standard scores of between 77 and 84.) (See Chapter 5, Section 5.5.2, Table 5.25 and Figure 5.47). The poorer results exhibited by the children with hearing impairment, in relation to the Listening Recall, have also been found by other researchers who have utilized a similar test (Hansson et al., 2004; Willstedt-Svensson et al., 2004). The Listening Recall task not only assesses verbal working memory, but it is also dependent upon a child's ability to comprehend the instructions, the vocabulary utilized within the sentences and the concept of true or false. The interaction between all of these variables, alongside a child's delayed vocabulary and linguistic abilities may adversely affect their scores, thus not reflect many children's true verbal working memory abilities. An additional variable that may also have had a negative impact on the research participants' results is their difficulties in recalling words.

The age appropriate findings in relation to Backward Digit Recall show that there appear to be no major deficits with central executive functioning, which co-ordinates processing across modalities. The findings from the current study in relation to the Backward Digit Recall are in contrast to those of many other researchers who evaluated both forward and backward digit recall in children with hearing impairment, in that their participants displayed poorer abilities than normally hearing children in Backward Digit Recall (Harris et al., 2013; Harris et al., 2011; Pisoni et al., 2011; Pisoni and Cleary, 2003; Pisoni et al., 2008). The relationship between Backward Digit Recall and long-term language age outcomes is tenuous, however. Pisoni et al. (2011) found that the adolescents in their follow up study performed less well on Backward Digit Recall as teenagers than when they were aged between 8 and 9 and yet, the majority (i.e. 88%) of the teenagers in their study still achieved age appropriate language scores. The clinical implications of these findings suggest that perhaps Backward Digit Recall is a more sensitive indicator of a delayed trajectory of language development when utilized with younger children with hearing impairment. It is possible that the use of the Counting Recall task from the WMTB-C and AWMA or the Informal Memory Test, devised for the purposes of the current research, will provide additional information regarding verbal working memory abilities in children with hearing impairment.

6.5.3 Visual short-term memory and working memory

The children in the current study achieved age appropriate scores on tests that assess visual short-term memory (Block Recall task) and visual working memory (Odd One Out task from the AWMA) (See Chapter 5, Section 5.5.3 and Table

5.26). Their age appropriate scores on these assessments emphasize that these children do not have generalized storage or processing difficulties. The results of the Odd One Out task, which evaluated visual working memory, address whether there are difficulties with the functioning of the central executive. The central executive is not a domain specific system, but instead processes information from both visual and verbal subsystems. The findings from this test demonstrate that there are no difficulties within the central executive and therefore processing of information remains unaffected. All six participants exhibited age appropriate standard scores on this test (See Chapter 5, Section 5.5.3, Table 5.26 and Figure 5.48). These results support those of Wass et al. (2010) and Lina-Granade et al. (2010) who found that their participants exhibited visual working memory abilities equal to those of their normally hearing peers. The implications of these findings are threefold. The first being that the deficits that the children display are related to verbal short-term memory functioning (i.e. storage) and not working memory (i.e. processing). The second implication is that there is added benefit from using multiple assessments across both the visual and verbal domains. This enables a more comprehensive exploration of short-term memory and central executive functioning across both modalities. The third relates to management, in that the results from the current research showed that the visual modality is an area of relative strength for this subgroup of children with hearing impairment and LLD. This would suggest that more visual support in the form of pictures, written words or objects should be utilized in educational and therapeutic management as a way in which to reduce demands upon verbal short-term memory.

6.5.4 Informal Memory Test

The development of the Informal Memory Test arose from the need to evaluate verbal and visual working memory using the same words (See Chapter 4, Section 4.12.1 for a detailed description of the test and Appendix 11 for the words and pictures used in this administration of this assessment). The Informal Memory Tests evaluated the verbal and visual memory abilities of younger, typically developing children with comparable language levels to the children in the case series. Their results on the Informal Memory test were then compared with the case series of children with hearing impairment and LLD. The verbal task required children to verbally recall names of objects from the same semantic category that were said to them. The child was asked to recall objects in size order from smallest to largest. The visual task required the children to label the pictures, which were placed in front of them in a non-specific order. The pictures were then removed, and the child was asked to recall the objects from smallest to largest. The results showed that the children with hearing impairment performed better on the visual task than the verbal task (See Chapter 5, Section 5.6, Table 5.27 and Figure 5.49). This pattern is different from the normally hearing children who completed both tasks equally well (See Chapter 5, Table 5.28). Only two of the children with hearing impairment and LLD improved their raw score on the verbal task over the duration of the study (See Child C: Table 5.9 and Child E: Table 5.15) while the other children's raw scores remained static. Child B (See Table 5.6) who was the oldest of the participants achieved raw scores for the visual memory task at ceiling (i.e. 25). The Informal Memory Test was used with much younger normally hearing children and therefore it is hypothesized that this task was presumably too simple for Child B given her chronological age and cognitive level. Nonetheless, the poorer verbal test results for the children with hearing impairment are understandable in light of these children's difficulties in the storage and retrieval of words, as exhibited by the Word Recall task discussed previously.

The Informal Memory Test was first administered to forty normally hearing children and was found to be sensitive to developmental changes. It is acknowledged that there are no full psychometric data related to this test (See Chapter 4, Section 4.12). However, although not a robust standardized assessment, the findings from the Informal Memory Test support the current study's previous findings, which are that the children with hearing impairment are functioning differently to normally hearing children in relation to verbal and visual working memory abilities. The children with hearing impairment and LLD consistently exhibited higher mean raw scores in visual working memory task (i.e. 20.22) than verbal working memory task (16.03). This is in contrast to the normally hearing children who exhibited mean raw scores on both the visual and verbal tasks that were virtually the same. That is to say, that the mean raw score for the normally hearing children's raw scores on the verbal task was 20.675 and the visual task was 20.300.

The wider application and standardization of the Informal Memory Test may allow for the further evaluation of children with hearing impairment with and without LLD. These findings would allow for a greater understanding of children with hearing impairment in relation to their normally hearing peers. The use of the same task across both modalities allows for a direct comparison of verbal and visual memory abilities and is innovative in its approach. The standardization of this this test across a larger sample and a wider age range would make this a valuable tool for clinicians.

6.6 Memory profiles and how they compare to other populations of children

In summary, the verbal short-term memory and working memory findings from the current study demonstrate that the children with hearing impairment and LLD do not exhibit generalized short-term memory and working memory difficulties but their deficits are located within the verbal domain and specifically within verbal short-term memory. The children with LLD exhibit difficulties in the storage and access of words, but display strengths in visual short-term memory and working memory (See Chapter 5, Table 5.26 and Figure 5.48). The current study group's profiles are very similar to each other, despite the wide age range of the participants. The current study's findings in relation to the memory abilities of these children with LLD cannot be directly compared with other studies in the field of hearing impairment, because other studies have used different memory tests and there is a limited number of studies that have utilized multiple measures of verbal and visual short-term memory and working memory. However, the current research demonstrated that this population of children with hearing impairment and LLD display a unique profile of verbal and visual memory abilities.

In an interesting and innovative set of studies, Alloway et al., (2009b) and Alloway and Archibald (2008) have shown that there are very distinctive memory profiles for children with specific language impairment, attention deficit hyperactivity disorder, developmental co-ordination disorder and Asperger's Syndrome. This detailed profiling of memory abilities has yet to be conducted in children with hearing impairment. The current study did not utilize the complete battery of assessments from the WMTB-C or the computerized version of the tests from the AWMA as Alloway et al. (2009b) did. Even so, the results can be compared by individual test with each of the developmental disorders. The profile for the children with hearing impairment and LLD is compared to other profiles found by Alloway et al. (2009b) in Table 6.1. The following is a comparison between the children with hearing impairment and other populations of children with developmental disabilities assessed by Alloway et al. (2009b).

Table 6.1 ***Group mean standard scores for verbal & visual short-term memory and working memory abilities***

	HI & LLD (n=6)	SLI (n=15)	ADHD (n=83)	DCD (n=55)	AS (n=10)
Digit Recall	83.45	84.33	94.73	82.55	85.70
Word Recall	79.39	83.93	98.81	90.24	76.40
Non-word Recall	110.00	82.93	103.08	93.62	80.10
Backward Digit Recall	88.17	82.20	89.24	85.45	90.70
Listening Recall	80.33	85.67	90.65	89.15	94.10
Block Recall	103.61	92.20	87.99	80.20	86.60
AWMA Odd One Out	116.70	95.80	88.25	85.84	97.60
	Current Study	***Alloway et al. (2009b)**			

*children are aged between 8;8 and 9;10 years (mean standard deviation was 16 months)

HI = Hearing impairment and Language Learning Difficulties
SLI Specific Language Impairment
ADHD = Attention Deficit Hyperactivity Disorder
DCD = Developmental Co-ordination Disorder
AS = Asperger's Syndrome

Each group has similarities with one other but overall quite differing patterns of ability. The children in the current study exhibit age appropriate scores in Non-word Recall, but significantly poorer scores in Word Recall. This profile compares to children with specific language impairment who display similar mean standard scores in relation to Digit Recall but poorer scores in Non-word Recall. The specific language impairment group also exhibit better scores in Word Recall at than the study group. The specific language impairment group appear to have a consistent profile of verbal short-term memory abilities, which is considerably different from the children with hearing impairment and LLD. The children with specific language impairment also have mean scores within one standard deviation for Listening Recall, but poorer scores in Backward Digit Recall. These findings are substantially different from this group of children with hearing impairment and LLD who display age appropriate scores in Backward Digit Recall task but below average scores in the Listening Recall task (See Table 6.1). As discussed in Section 6.5.1, the children with hearing impairment have obvious difficulties with recalling words, which appear to have had an adverse impact upon their scores in the Listening Recall task, in that this task requires the child to judge the correctness of a statement, as well as recalling the last word in the sentence. Thus, the Listening Recall task places a greater demand on accessing the long term memory than the Backward Digit Recall task. Both the specific language impairment group and the study group exhibit age appropriate abilities in visual short-term memory and working memory. However, the children with hearing impairment and LLD exhibit higher standard scores on both of the visual short-term memory and working memory tasks than the children with specific language impairment. This may be due to cortical reorganization that children with hearing impairment experience as a result of auditory deprivation (see Chapter 2, Section 2.2).

The scores of these children with hearing impairment, however, are significantly greater than those of the children with developmental co-ordination disorder, who display visual short-term memory and working memory abilities that are considerably poorer than those of the children with hearing impairment and specific language impairment. Alloway et al. (2009) suggest that the lower scores of these children may in part be due to the motor component of the test whereby children with developmental co-ordination disorder are required to touch the computer screen. However, the children with developmental co-ordination disorder displayed greater scores in the Odd One Out test which also required them to touch the computer screen multiple times. It may be that children with developmental co-ordination disorder are experiencing perceptual difficulties with this task, as is common in many children with developmental co-ordination disorder (Alloway and Archibald, 2008). The children with hearing impairment also exhibit significantly better scores in Non-word Recall test and visual short-term memory and working memory than the children with developmental co-ordination disorder. Conversely, the children with developmental co-ordination disorder display better scores in Word Recall and Listening Recall than the children with hearing impairment. These findings suggest that children with developmental co-ordination disorder have well defined phonological and lexical representations and are efficient at accessing their long term memory, which is quite different from the children with hearing impairment and LLD.

The children with attention deficit hyperactivity disorder display age appropriate abilities in verbal short-term memory but poorer scores in verbal working memory and visual short-term memory and working memory. However, their scores in verbal short-term memory remain within one standard deviation. These results show that they appear to have some weaknesses across both modalities in relation to working memory. That is to say that they exhibit mild difficulties in processing of information, but not storage. In view of the nature of attention deficit hyperactivity disorder, their difficulties may be related to their problems with attending to the task itself and not necessarily working memory. Their profile is significantly different to this group of children with hearing impairment, in that visual short-term memory and working memory are areas of strength and verbal short-term memory, in particular Word Recall and Digit Recall, are poorer than for the children with attention deficit hyperactivity disorder. The children with Asperger's Syndrome exhibit deficits in verbal short-term memory with two of the three subtests being more than 1 standard deviation below the mean and the Digit Recall task being just within normal limits with a standard score of 85.70. Their profile is noticeably different to the children with hearing impairment, as their scores on Non-word Recall are well within the age appropriate range, but they have poorer scores in visual short-term memory and working memory. Interestingly, their mean standard scores in the Digit Recall and Word Recall tasks are similar to those of the children with hearing impairment. These children may also have difficulties with poor quality phonological and lexical representations and weaknesses in accessing the long term memory.

In summary, these findings demonstrate that while each population of children with developmental disorder may have some similarities, each group exhibits quite differing patterns of abilities and therefore distinctive memory profiles. The children with hearing impairment and LLD display a unique memory profile, which is markedly different from other children with developmental disorders such as specific language impairment and possibly from other children with hearing impairment whose language is within the typical range. Specifically, they exhibit the greatest mean scores in Non-word Recall, visual short-term memory and working memory compared with any other population of children with developmental disorders. They also have the second lowest score in Word Recall, at almost two standard deviations below the mean. The children with hearing impairment are the only group of children to achieve greater scores in Backward Digit Recall than Listening Recall. This difference in Listening Recall scores in relation to the children from the Alloway et al. (2009b) study appears to be as a result of the children with hearing impairment's difficulties in accessing words from their long term memory. The children with hearing impairment also exhibited a greater difference between the scores on the visual working memory test (i.e. Odd One Out) and the visual short-term memory (i.e. Block Design) than any other population of children. This difference may be due to the interactive nature of the Odd One Out test, which was administered via the computer.

6.7 Contribution to the theoretical understanding of memory and language abilities in children with hearing impairment and LLD

This study is the first longitudinal study to investigate the population of children with hearing impairment who display extremely poor spoken language outcomes. This study has contributed to an increased understanding of the long-term vocabulary and language deficits that this population of children exhibit. The children with LLD exhibit the same pattern of vocabulary development as other children with hearing impairment, which is to say that their expressive vocabulary is in advance of their receptive vocabulary. This subgroup of children with LLD also experience difficulties in Recalling Sentences and the use of appropriate grammar as other children with hearing impairment do. However, the children with LLD exhibit difficulties that are more exaggerated than other children with hearing impairment. It is hypothesized that the children's combined delays in vocabulary development and semantic knowledge, alongside deficits in phonological and lexical representations and poor lexical organization, have led to their pervasive difficulties in spoken language learning. These children's exceptionally poor ability to learn and retain new words and the delayed development of vocabulary, alongside the memory findings, are clinical indicators of difficulties in encoding and storing words. The children with hearing impairment and LLD struggled to achieve the requisite foundation of vocabulary of at least 200 words as young children that have enabled them to learn words more efficiently. Their early word learning was a protracted process, which meant, in practice, that over time, they were falling further and further behind their normally hearing peers. Therefore, the gap in their vocabulary and language development between themselves and their normally hearing peers was unable to be lessened even when provided with intensive educational support.

This study is the first known research in the field of paediatric hearing impairment to utilize tests from the WMTB-C and AWMA, and in particular single syllable Non-word and Word Recall tasks, as well as with Digit Recall. The additional information gained from the use of different tests such as the Word Recall task, has uncovered that deficits in verbal short-term memory may not be solely due to undefined phonological representations, but may also be a result of difficulties in accessing the long term memory and poor lexical organization. The thesis has also provided additional evidence for this population of children that their difficulties are in the storage and retrieval of words, but not processing. These findings have therapeutic implications for the management of this subgroup of children with hearing impairment, which are discussed in Section 6.9. The study also made use of multiple memory assessments across both verbal and visual modalities, as a way in which to create memory profiles for this population of children.

6.8 Limitations

<u>*Limitations related to the methodology*</u>

Although the selection of children for the study was purposive, the identification of these particular six children for this study was available as a result of opportunity sampling. An evaluation of the language and memory abilities of another six children *may* have provided different results, although the children were typical of a population frequently met in clinical practice, who, despite optimum aided hearing and therapeutic intervention fail to achieve the expected gains in language learning, as evidenced by the literature. The current research did not compare chronological age or hearing age matched peers with hearing impairment to the children in the case series (See Chapter 4, Section 4.3). This may have illuminated other useful findings that have been addressed by the current study. Predictably, the use of assessments which are standardized on normally hearing children allowed for comparison with their normally hearing peers. It would have been desirable, in addition, to match with a control group of children with hearing impairment, however this would be extremely difficult, given the heterogeneous nature of the population of children with hearing impairment.

There is a tension between researching the abilities of children of the same age, which may provide deeper insight into language and memory abilities at one chronological point, with the advantage of investigating children from a wider age range, which gives a broader picture of performance at different age points. The inclusion of the wide age range in this study may therefore be viewed as a limitation of the study. It is argued, however, that the current study benefitted from the investigation of children across a wide variety of ages, as memory abilities continue to develop into adolescence and a cohort of children of the same age may have only displayed their memory abilities for that developmental stage. The findings from the current research consistently demonstrated over the duration of the study, that the study group exhibited similar memory profiles, irrespective of their different chronological ages. For the children in this study, therefore developmental issues had less of an impact upon the memory findings of the study. As the participants' characteristics are similar to many other children with hearing impairment and all six children display similar memory and language profiles, it is suggested that a subgroup of other orally educated children with hearing impairment and LLD may well exhibit comparable patterns of development.

A final limiting factor may be that a single person, the researcher, administered the assessments (See Chapter 4, Section 4.32). A study of inter-rater reliability was not undertaken, for multiple reasons. Firstly, there is a limited pool of speech and language therapists specializing in paediatric hearing impairment and cochlear implant. Secondly, there was no availability of additional funding, and finally the process of evaluating inter-rater reliability was not feasible due to limited time.

Some of the administration of assessments were video recorded and can be made available for research audit, with permission from the participants' parents. In addition, as part of the study's annual assessment process, information gathering from other professionals (i.e. teacher of the hearing-impaired, speech and language therapist, and class teacher) regarding the children's educational and linguistic development enabled a greater understanding of the impact of their difficulties. In the annual meetings, the children's teachers stated that the children still had difficulties in learning new curriculum-related vocabulary and continued to exhibit poor sentence structure during conversational speech. Thus there is a triangulation between differing approaches to educational assessment which serves to support the findings in this research.

Limitations related to the findings

The current study was limited to six children with hearing impairment and LLD. The results of the study therefore, need to be interpreted with caution due to small numbers, which can influence mean group scores. The case series design provided a greater depth of knowledge about this particular group of children than a large-scale study may have been able to. However, the findings from the current study are not generalizable, in that other variables, as identified by previous researchers, also have an impact upon spoken language development. That is to say that the educational experience of the children, their non-verbal IQ, their family support, and the educational attainment and socio-economic status of parents may have affected their outcomes. The findings from the current study are also restricted to orally educated children in a mainstream school or a school for children who are hearing-impaired. In the absence of other research, it is unclear whether the memory profiles would be different for children who utilize total communication or sign language as their primary mode of communication.

As a result of using a different battery of memory assessments than previous researchers, it is also uncertain whether all children with hearing impairment will display the same or similar memory profile of the case series. It would be useful to compare the case series of children who participated in this study with a cohort of children with hearing impairment who display age appropriate vocabulary and spoken language abilities. These results would have provided greater insight into the memory profiles for children with hearing impairment and distinguished whether the case series of children display a unique memory profile or one typical of children with hearing impairment.

The theoretical interpretation of the results, that is that the children had considerable difficulties in word recall due to poor quality phonological and lexical representations, as well as the possibility of inadequate semantic representations (Alt and Plante, 2006) in the long term memory (Maniela-Arnold-and Evans, 2005) is open to challenge. The children in the case series also displayed extremely poor vocabulary development which were attributed to these weakness in word recall, as well as difficulties with word storage and poor lexical organization. Each is a hypothetical interpretation and not a definitive answer. Their difficulties may also be related to a weakness in accessing words, as well as poor executive function.

6.9 Application to clinical practice

Researchers continue to hypothesize about why some children with hearing impairment achieve age appropriate spoken language and others do not. The clinical implications of the findings from the current study relate to both the assessment and management of children with hearing impairment.

6.9.1 Assessment of verbal short-term memory and working memory in multiple ways

Thus far, researchers in the field of hearing impairment have typically used just one test in the evaluation of verbal short-term memory and working memory. Traditionally researchers have used either a Digit Recall task or a multisyllabic Non-word Recall test to evaluate verbal short-term memory. It is unclear as to why other researchers have not utilized a single syllable Non-word Recall test, as it has been well documented that the traditional Non-word Recall tests are a less sensitive measure of verbal short-term memory as children get older (e.g. Baddeley, 2003; Simkin and Conti-Ramsden, 2001). Digit Recall has been found to be highly correlated with vocabulary development (Gathercole et al., 1997a; Gathercole et al., 1999). It also relies on the semantic knowledge related to numbers which are familiar to children. This may enhance their recall ability in this task.

The current study made use of a battery of verbal and visual short-term memory and working memory assessments as a way in which to better understand the strengths and weakness in children with hearing impairment and additional LLD. The use of multiple tests allows for a more comprehensive evaluation of verbal short-term memory and working memory. The exploration of verbal short-term memory utilizing different assessments such as single syllable non-words or words would illuminate patterns of development that have previously gone unnoticed and consequently support intervention decisions. The move away from the traditional Non-word Recall test to the single syllable Non-word Recall test may well provide researchers, teachers and clinicians with new knowledge regarding verbal short-term memory. The multisyllabic Non-word Recall task not only assesses the functioning of the phonological loop, but also evaluates speech perception, phonological encoding and motor planning (Gathercole et al., 2004; Gathercole et al., 2005). This task also makes use of existing lexical and semantic knowledge, which are areas of deficit in children with hearing impairment. If children display lower standard scores on this task, it may only reflect deficits in phonological and lexical representations, difficulties in accessing and storing words in the long term memory and/or poor lexical organization. If multiple tests of verbal short-term memory are used, the results will yield additional information with regard to verbal short-term memory, as differing levels of semantic knowledge and lexical access are required for each of these tasks.

Again, many researchers have utilized a single measure to evaluate verbal working memory. The tasks most frequently employed by researchers are either the Backward Digit Recall test or the Listening Recall Task. There is added benefit in using more than one assessment to measure verbal working memory, as different verbal working memory tasks are more or less dependent upon access to long term memory and semantic processing. For example, the Backward Digit Recall task does not place any significant demands upon semantic knowledge or require well defined phonological or lexical representations, which is in contrast to the Listening Recall task. This test relies on the comprehension of vocabulary items, as well as an understanding of attributes of objects and how they relate to one another. The use of two or more measures of verbal working memory enables weaknesses and/or strengths in memory abilities to become apparent, which can then be addressed within educational and therapeutic settings.

6.9.2 Creation of memory profiles

The use of multiple memory tasks with children with hearing impairment, which evaluate both verbal and visual short-term memory and working memory, would allow for the development of memory profiles. These findings in conjunction with results from language assessments could differentiate children with hearing impairment who achieve scores one standard deviation above the mean (i.e. standard scores between 105 and 115) from those who exhibit a slower rate of language learning, but within one standard deviation below the mean (i.e. standard scores from 85 to 90). These profiles could then be compared with profiles from children who display additional LLD. This information could allow for more effective intervention that is specifically tailored to meet their needs. With reference to the current group of children, the use of multiple tests has allowed for a greater understanding of their memory abilities that would have otherwise been overlooked, especially if only a single measure of verbal short-term memory and working memory were utilized.

6.9.3 Extremely poor vocabulary development

The vocabulary findings from the current study may go some way to providing support to speech and language therapists and teachers of the hearing-impaired in the identification of children with hearing impairment who may struggle to learn words. The children in the study exhibited exceptionally poor vocabulary development, even after many years of intensive therapeutic and educational support. Their long term difficulties in learning new vocabulary, as reported by their teachers of the hearing-impaired, may be an indicator of a child who will struggle to learn early acquired words or vocabulary related to the national curriculum. Their teachers of the hearing-impaired made statements such as, “The children appeared to have learned a new word in context but then could not retain it day on day.” This theoretical interpretation, which is that the children have impaired verbal short-term memory, limited semantic knowledge and poor lexical organization. This interpretation is further influenced by the study’s findings from the Word Recall task. That is to say that the children with hearing impairment and LLD had significant difficulties with recalling words, which require well-defined representations and efficient access to the lexicon. The extremely poor vocabulary development exhibited by the children with hearing impairment and LLD may be due to poor quality phonological representations and may also be influenced by inadequate semantic representations and degraded lexical representations in the long term memory. In either case memory is implicated and therefore, one of the focuses of intervention may be to create more robust, well-defined representations.

It is argued that by increasing semantic knowledge, which provides the “adhesive” to hold phoneme sequences together to form words, children with hearing impairment who are having word learning difficulties will be able to store words more efficiently, have greater lexical organization and thus acquire vocabulary more quickly. It is suggested, in line with Nittrouer et al. (2013), that intervention may want to focus on increasing lexical and semantic knowledge, as a way in which to support storage in working memory. This therapeutic programme should also make use of the strengths in visual short-term memory that children with hearing impairment demonstrate.

6.9.4 Summary

The broad aim of the research study was to investigate factors associated with vocabulary and language development in six children with hearing impairment who experienced difficulties in language learning. The current study made use of longitudinal data, which allowed for the exploration and identification of profiles of development in this subgroup of children with hearing impairment. The study group was drawn from the population of orally educated children with hearing impairment who did not achieve age appropriate language despite relatively early fitting of their hearing aids or cochlear implant and consistent device use. The current group of children with LLD had difficulties in acquiring vocabulary and developing multiword utterances in the early stages of their language learning. They all continued to remain significantly delayed in their acquisition of vocabulary, grammar and syntax and exhibit weaknesses in their verbal short-term memory abilities. However, this cohort of children displayed strengths in visual short-term memory and working memory. It can be concluded that these children with hearing impairment and LLD exhibit a language profile, with particular reference to their morphosyntactic development, as well as their ability to recall sentences, that is considerably poorer than that of the majority of other children with hearing impairment. However, the children with LLD are following patterns of vocabulary development typical of children with hearing impairment, but at a significantly slower rate than the majority of their peers with hearing impairment. A substantial delay in the acquisition of vocabulary in the early stages of language development has been found to have a detrimental impact upon their acquisition of grammar and syntax. If early word learning could be accelerated through targeted therapeutic input, perhaps these delays in vocabulary acquisition and their impact upon language development could be lessened or even remediated.

6.10 Contemporary influences on the development of a therapeutic programme

The development of a therapeutic programme addresses the third objective of the study, that is

Objective 3: To develop a research and theory-driven intervention to pilot test the findings of the study

The exploratory therapeutic programme described in the next chapter made use of one contemporary model of language development based upon the work of Bloom and Lahey (1988), The Intentionality Model (Bloom and Tinker, 2001). The model by Bloom and Lahey (1988) outlines the essential elements for language development as *Content, Form* and *Use*. Bloom and Tinker (2001) subsequently added *Effort* and *Engagement* as variables that are integrated as part of language acquisition. These components can be understood as follows:

Content: the meaning of what is said (e.g. semantics). It consists of topics such as objects (e.g. Mummy, shoes) and object relations (e.g. kick the ball).

Form: the sounds of language (e.g. phonology), the smallest parts of speech that carry a meaning such as *ed*, *ing* (e.g. morphology) and word order (e.g. syntax).

Use: the use of language to meet a need or enable interaction with others (e.g. pragmatics).

Effort: the cognitive processes and effort needed in order to acquire vocabulary and language.

Engagement: "the child's emotional and social directedness for determining what is relevant for learning and the motivation of learning" (Bloom and Tinker, 2001, p.14).

The exploratory programme specifically focused upon early word learning and thus vocabulary development in young children with hearing impairment (See Figure 6.1). The ways in which children with hearing impairment are exposed to language, along, with the specific vocabulary targeted, are also variables that merit consideration in any programme of intervention. Lederberg and Spencer (2009) found that children with hearing impairment, who use spoken or sign language, follow a particular developmental pattern when learning new words. This process has been observed in other children with developmental disabilities (Dollaghan, 1987; Mervis and Bertrand, 1995; Weismer and Evans, 2002). This three-stage sequence involves: 1) direct explicit exposure to new words, 2) gradually reducing the number of direct exposures and 3) facilitating the inferences of the meaning of words from an initial exposure in a meaningful context. The developmental process of word learning relies heavily upon the type and intensity of input from others (See Chapter 2, Section 2.5). These authors concluded that children need a critical mass of vocabulary (i.e. approximately 200 words) to enable them to learn words in a less direct manner and that a considerable proportion of children with hearing impairment are slower at reaching this threshold than their normally hearing peers. Lederberg and Spencer (2009) suggest that children with hearing impairment may require additional time in the "direct" exposure phase of word learning. This may be a result of limited experience of incidental listening and language learning that children with hearing impairment encounter (Cole and Flexer, 2008). A visual representation of the literature that influenced the development of the programme of intervention for children with hearing impairment can be seen in Figure 6.1.

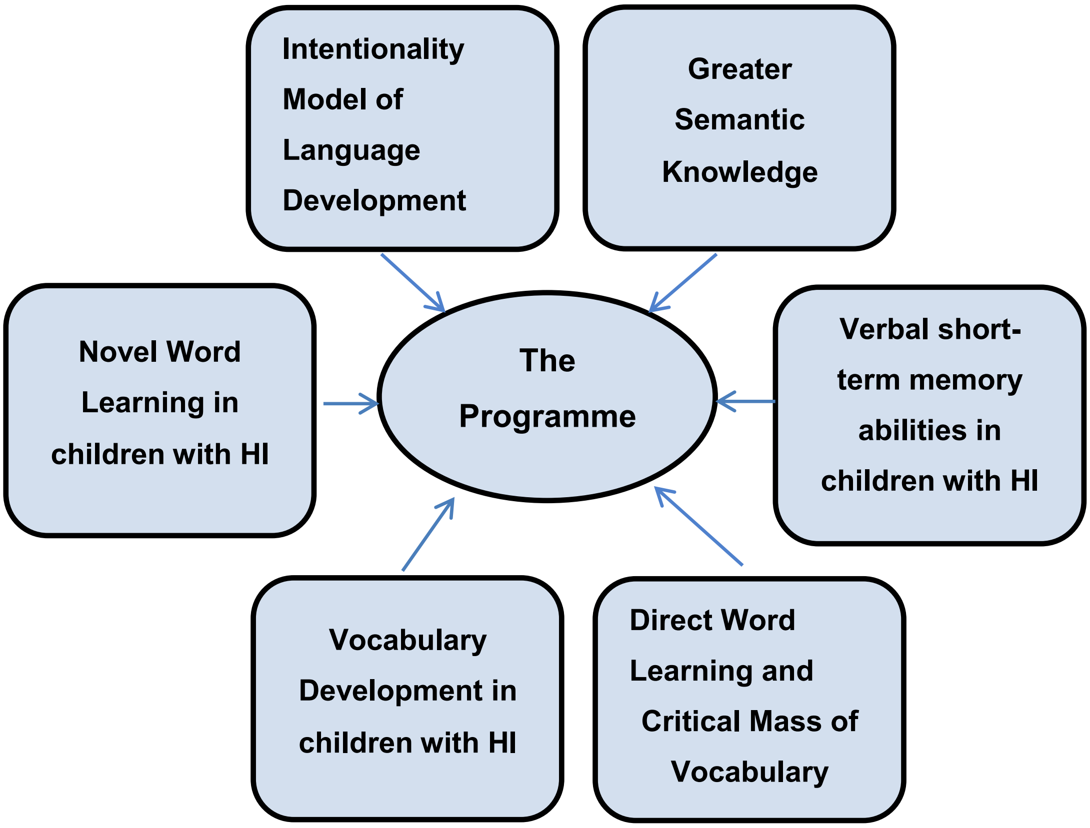

Figure 6.1 **Contemporary knowledge that influenced the development of the therapeutic programme**

As a result of the vocabulary and word recall findings from the current study, as well as other authors' work, it is argued that lexical and semantic knowledge should be therapeutically targeted in a different manner in the subgroup of children with hearing impairment who are having difficulty learning new words. It is acknowledged that increased or deeper semantic knowledge has a positive influence upon the quality of phonological and lexical representations, thus enabling more efficient storage and recall of verbal material (Howard and Nickels, 2005). Thus it is asserted (Steele and Mills, 2011), and supported by the current study, that a programme of intervention should target early word learning and vocabulary development that focuses upon creating a "deep" understanding of words, as well as increasing lexical organization. The use of semantic categories in the form of pictures, alongside other techniques for enhancing word learning will enable the development of vocabulary that has rich foundations built both in lexical and semantic knowledge (See Chapter 7, Section 7.3 and Figure 7.2).

When learning new vocabulary, the proficiency with which to categorize words alongside the ability to encode the word and attribute meaning to it permits the initial stages of word learning to begin. Children, irrespective of disability, make use of information related to the semantic category of words when learning new vocabulary. Children with hearing impairment exhibit the same abilities in categorization as normally hearing children. Categorization abilities develop by the age of 2;6, regardless of a child's communication mode (Mervis and Bertrand, 1994). Semantic knowledge is the "glue" that helps to create clear phonological and lexical representations. If increased word knowledge can be linked to new vocabulary items, with semantic categorization, this will support children in acquiring words that have richer semantic networks and thus more robust phonological and lexical representations and greater lexical organization. This would aid storage of new vocabulary items, which has been found to be a particular area of difficulty for the children in the current study, as well as by Nittrouer et al. (2013).

In summary, the therapeutic programme in Chapter 7 grew out of expectations regarding vocabulary development and made use of the vocabulary findings and weaknesses in word recall abilities from the current study and knowledge gained from other researchers who investigated novel word learning (Gilbertson and Kamhi, 1995; Lederberg et al., 2000; Lederberg and Spencer, 2009; Mervis and Bertrand, 1995), vocabulary development (Geers et al., 2009; Moeller et al., 2007b; Nicholas and Geers, 2013), and memory in children with hearing impairment (Harris et al., 2013; Nittrouer et al., 2013; Stiles et al., 2012).

Chapter 7 Exploratory Intervention

7.1 Introduction

Chapter 7 begins with a brief discussion of the background to the research, followed by an explanation of the rationale and an outline of the premises underlying the exploratory intervention study aims. This is followed by a discussion of the therapeutic programme and the strategies utilized in the therapeutic management of the two children with hearing impairment and additional LLD. The second part of the chapter outlines the recruitment procedures, the participant characteristics and data collection process. The third part of the chapter summarises the results and the final section of the chapter discusses the clinical implications of the study.

7.1.1 Background to intervention study

Memory training programmes have been explored as a possible way in which to improve spoken language outcomes in children with hearing impairment (Kronenberger et al., 2011; Nunes et al., 2014). The implementation of individualization programmes of therapeutic input is also another avenue that can be explored (Harris et al., 2013; Nittrouer et al., 2013; Pisoni et al., 2011; Stiles et al., 2012). The research objective for the current exploratory intervention was to develop a research and theory-driven intervention to pilot test the findings of the study (research objective 3). The intervention specifically targeted early word learning and vocabulary development, as the children in the longitudinal case series had exhibited long term difficulties in acquiring vocabulary. The clinical implementation of the current study's findings with regard to poor vocabulary development has the potential to allow for specific intervention that addresses the early word learning difficulties and deficits in verbal short-term memory (i.e. access and storage of words) that all the children in the current study exhibited. The focus of such a therapeutic programme would be to accelerate vocabulary development for this subgroup of children. This exploratory intervention programme is discussed below.

7.1 Rationale for an exploratory intervention study

Researchers in the field of hearing impairment have discovered that certain areas of language develop at different rates (See Chapter 2, Section 2.7 and Chapter 6, Section 6.3.2). Specifically, that receptive and expressive vocabulary shows the greatest increases in the early stages of development and that this progress is maintained over time (See Chapter 2, Section 2.6). That is to say that receptive and expressive vocabulary abilities can “catch up” more quickly than morphosyntactic abilities (Caselli et al., 2012; Duchesne et al., 2009; Geers et al., 2009; Tomblin et al., 2015) and many children with hearing impairment display age appropriate vocabulary levels by the age of 4;6 (See Chapter 2, Section 2.7). Researchers have hypothesized that difficulties in acquiring new vocabulary may be attributable to the poor ability to learn novel words and have found a significant correlation between novel word learning abilities and vocabulary development (Gathercole et al., 1997a; Gathercole et al., 1999; Lederberg and Beal-Alvarez, 2011; Lederberg and Spencer, 2009). Thus, those children who can learn novel words in less structured, indirect contexts exhibit larger vocabularies (See Chapter 2, Section 2.5).

It has been recognized that children with hearing impairment learn fewer novel words than their normally hearing peers (Gilbertson and Kamhi, 1995; Houston et al., 2005; Lederberg et al., 2000; Lederberg and Spencer, 2009; Pittman et al., 2005; Stelmachowicz et al., 2004) (See Chapter 2, Section 2.5). The ability to learn novel words is related to the proficiency with which a child can encode phonological information, their vocabulary size and their semantic knowledge. Researchers are now beginning to identify those children with hearing impairment who exhibit typical word learning trajectories and differentiate them from those children who display extremely delayed vocabulary development. As described in Chapter 2, Section 2.6, Moeller et al. (2007b) found four patterns of vocabulary development in young children with hearing impairment. The slowest developing group of children with hearing impairment exhibited an exceptionally delayed pattern of vocabulary acquisition. These difficulties in acquiring vocabulary were also apparent in the six children with hearing impairment in the current study. Their delays in vocabulary development did not vastly improve over time and the participants continued to display standard scores in receptive and expressive vocabulary between 63 and 78 (See Chapter 5, Section 5.4. and Chapter 6, Section 6.3).

This exploratory intervention study is a practical application of the theoretical interpretations (See Chapter 6, 6.8) which resulted from the longitudinal study. These interpretations were utilized alongside findings from associated literature, as a way in which to investigate whether targeted therapeutic input will lead to changes in vocabulary or spoken language development in two young children with hearing impairment over a twelve-month period. The knowledge gained from this intervention study provides initial evidence for ways in which to enhance word learning and language acquisition for children with hearing impairment who exhibit greater than expected difficulties in early word learning and poor spoken language development.

7.2 The premises of the intervention study

This intervention study was exploratory in its nature. It was conducted in order to gain insight into methods by which to enhance, therapeutically, early word learning and vocabulary development in young children with hearing impairment. The two children in the therapeutic intervention study present with similar histories of difficulties in early word learning, poor vocabulary development and substantial language delays as the children in the longitudinal study. That is to say, that the two children in this exploratory intervention study can be regarded as "younger versions" of the children assessed and examined previously in this thesis. The therapeutic intervention study was designed to focus on these areas of difficulty, whilst incorporating theoretical interpretations of the vocabulary and word recall findings from the longitudinal study. It is hypothesized that the vocabulary and language learning difficulties of the cohort of children with hearing impairment involved in this research appear to be related to the poor quality of phonological and lexical representations stored in the long term memory, as well as poor lexical organization. These weakness in combination with other variables, such as delayed access to auditory input, the hearing loss itself and the different listening experience that children with hearing impairment encounter, combine to create the pervasive language learning difficulties (LLD) observed in the children in the longitudinal study (See Figure 7.1).

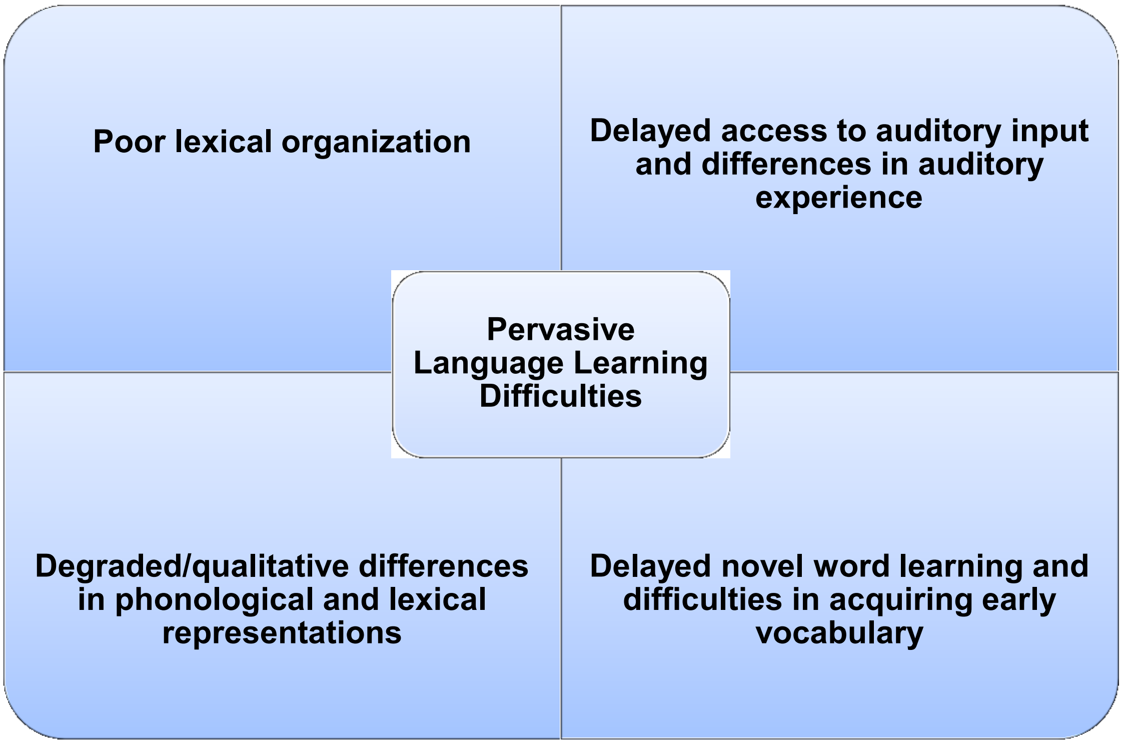

Figure 7.1 **The interaction between variables creating pervasive LLD**

7.3 The programme

The aim of the study was to explore whether specific intervention, which focused upon early word learning and the development of greater semantic knowledge and lexical organization along with more robust phonological and lexical representations, was associated with changes in vocabulary or spoken language development. The primary focus of the therapy was to help each child to reach the critical mass of vocabulary that would allow them to learn vocabulary in a more indirect manner (Lederberg et al., 2000; Lederberg and Spencer, 2009), whilst creating richer clearer representations and better lexical organization. The hypothesis was that through receiving intensive direct input and increasing semantic knowledge associated with new vocabulary, children with hearing impairment will acquire words that have more robust, well-defined representations. This, in turn, would possibly allow for easier, more efficient storage of words and thus increase their rate of word learning. As these children with hearing impairment already struggled to acquire vocabulary at a similar rate to their peers with hearing impairment, it is likely that they would require a larger repertoire of vocabulary items before they are able to learn new words in a more indirect way (Lederberg and Spencer, 2009) (See Chapter 6, Section 6.9.5 for a discussion of the theoretical framework for the programme). The programme utilized the strengths in visual memory by incorporating the use of pictures and objects to support word learning, increased semantic knowledge, lexical organization and the development of robust phonological and lexical representations

The focus of the programme is “needs led.” That is to say that specific vocabulary items that the child needed to functionally communicate were the primary targets for intervention (See Table 7.1). As this was an exploratory intervention study, specific to these two children, the vocabulary chosen was contextually functional to them. High frequency words were utilized initially, as well as more noun based words than verbs. Nouns are learned, proportionally, in greater numbers and are also easier to represent visually and require less processing resources than verbs (Fenson et al., 2007). However, as the children in the exploratory study were coming to word learning at a later age than normally hearing children, they had a greater need for other word types, such as verbs and adjectives, to be included in their developing vocabulary. The programme made use of any of the children’s everyday experiences in order to create a “bank” of words from which to build upon.

The teachers of the hearing-impaired and support staff used the pictures of members of the semantic categories of target words in individual sessions (e.g. foods, people etc.). These vocabulary items were then focused upon throughout the school day through play and structured activities. This process of vocabulary exposure enabled richer phonological and lexical representations to develop, as well as enhancing word knowledge. The objects chosen were those that were the most intrinsically functional to the children (i.e. the words met a need). The intervention targeted a small group of “high impact” words individual to these children that would allow the children to communicate their needs more effectively. The functionality of the words was contributed to the children’s everyday experiences and ability to interact with their peers. Learning words such “help me,” “my turn,” “no,” “more” enabled the children socialize more effectively with their friends and family. The examples of the vocabulary to which the children were exposed are presented in categories in See Table 7.1 and Figure 7.2. The target words were modelled by the classroom teacher and teaching assistants, as well as encouraging the children to use these words functionally to meet a need within the school environment.

The vocabulary also needed to be at the appropriate, developmental level for the child in relation to their auditory development (Ling, 1989). That is to say that the use of target words that were all one syllable words or words that sounded similar would have made it too difficult for the children to perceive the differences between those words. Therefore, some words that were focused upon early in the children’s word learning were “highlighted” through the use of intonation, pitch variation and repetition in order to make words more acoustically interesting and perceptually accessible. For example: sounds associated with objects referring to meaningful objects such as slide was reinforced as “up up up whee” or roundabout was exposed to the children as “round and round and round.” This exposure also enabled the clear repetition of vowels, which are the nucleus of all words. The acquisition of clear vowels is necessary in order for children to develop intelligible speech (Ling, 1989).

Table 7.1 ***Vocabulary development in the context of everyday experiences***

Core Vocabulary	Category	Context	Justification
Water, milk, juice, cocoa	Drinks	Individual sessions, classroom learning and snack time	Contextually functional language that meets an intrinsic need, high impact and life-long usage
Orange, apple banana, pear, grapes	Fruit	Individual sessions, snack time and home	Contextually functional language that meets an intrinsic need, high impact and life-long usage
Biscuit, sweets, cake, ice-cream	Treats	Individual sessions, home and school	Needs led vocabulary which is highly motivating
Round and round, up up up whee, stop, go, down	Playtime	Individual sessions, outdoor play at home and school/ symbolic play	Contextually functional language that is intrinsically meaningful
My turn, help me, more, all gone, no, toilet	Social words	Individual sessions, school and home	Contextually functional language that meets a need
Toilet, bath, dinner, bedtime	Home Routines	Individual sessions, symbolic play and home	High impact and contextually functional language, life-long usage
Mum, Dad, siblings, teachers, friends	People	Home and school	High impact, life-long usage and long term value
Cry, sit down, walk, fall down, jump, wash your hands	Action words	Individual sessions, home and school/symbolic play	High impact and contextually functional language, long term usage

Procedure for the teaching of new vocabulary items

Any new vocabulary was introduced in individual sessions via a sorting task that included pictures of known words. The child was given a pile of pictures and asked to organize them into “things that go together” (i.e. semantic categories). There were initially 5 pictures of target vocabulary, whereby three pictures represented words that were familiar and the two remaining pictures were new to the children. This task was initially completed in silence, so as not to overload the child; however, the children often named the objects that they knew. Their receptive vocabulary was developed in a systematic manner whereby all new vocabulary items were introduced and semantically linked to other items through the use of categorization of pictures and direct teaching (Lederberg and Spencer, 2009). The individualized Vocabulary Webs were developed for each child and used as the basis of school related activities; both play and routine activities such as snack time. Figure 7.2 and Table 7.1 provides examples of early vocabulary items, which are organized into semantic categories and how they are connected to other words that were meaningful to the children. The children could then have repeated meaningful exposures through individual sessions, play and everyday school experiences of target vocabulary items. The children, therefore, heard that word in a meaningful context on several occasions on a daily basis from their teacher of the hearing-impaired, class teacher and/or specialist support assistant.

The majority of the activities were pragmatically appropriate, that is to say that children were not asked to name objects like a "test," but interacted with teachers and therapist using the new vocabulary to fulfil a request, make a choice or comment. Daily events such as snack-time were used in this manner, whereby the children needed to ask for which drink (e.g. milk or water) and which fruit (e.g. apple, orange, and pear) they would like. A further example includes language used in outdoor play, which is a daily experience for most young children in Nursery and Reception classes. The children frequently played outside and had access to playground equipment. Therefore, staff could provide repeated exposures to spoken language that was both meaningful and useful to the children. The language targeted was "up up up whee" (slide), "round and round and round" (roundabout), "down" (steps), and "jump." The vocabulary was reinforced beyond the playground to therapeutic session whereby the children played with PlayMobil® toys that utilized the same vocabulary. Two word combinations were developed by combining two known vocabulary items, again in a functionally meaningful context (See Figure 7.2). For example, "More milk" or "No bananas."

The long-term aims of the therapeutic intervention would also be to target grammar, morphology and syntactic development, as these areas of development are areas are also at risk of delayed development. This has also been recommended by other researchers who found these areas in danger of poor development, especially in the context of the degraded auditory input children with hearing impairment experience (Boons et al., 2012; Nittrouer et al., 2014).

Techniques and strategies for enhancing word learning

When the children were being exposed to these “multi-purpose” meaningful words, professionals made use of the following techniques and strategies for enhancing word learning. They included: presenting auditory information first before the object or action, linking new vocabulary to familiar vocabulary, using speech at a slower rate, using exaggerated intonation, pitch variation and meaningful repetition as a way in which to emphasize words. For example: “Where are your **shoes**? “Your **shoes** (pointing to the child’s feet)?” “Here are my **shoes** (pointing to her own **shoes**.” “We have the **shoes**” (whilst holding the child’s shoes up and showing them). Other techniques also included using sabotage and making silly mistakes as a way in which to encourage the children to use target words in a meaningful way to meet their needs (Cole et al., 1992; Cole and Flexer, 2008). This approach to developing the children’s language was utilized in conjunction with the compensatory strategies for verbal short-term memory and working memory difficulties listed below (Gathercole and Alloway, 2008; Vance, 2008; Vance and Mitchell, 2005) (See Chapter 3, Section 3.7.1).

- Repetition of target vocabulary
- Pauses of three seconds to enable the child to comprehend and use the target vocabulary in a meaningful communicative situation
- Modelling the target words and how they are used in a variety of contexts
- Creation of semantic connections through the use of pictures and toys related to the vocabulary targets (See Figure 7.2)
- Providing visual support in the form of objects and pictures
- Introducing new words in relation to already existing target words (See Figure 7.2)
- Explanation of the context within which the target word is found or used
- Daily review of target words
- Chunking of information

Figure 7.2 **Vocabulary Webs**

7.4 Method

7.4.1 Ethical Approval

Ethical approval for this study was obtained from the author's University Ethics Committee, a local National Health Service (NHS) Research Ethics Committee reference number 09/H1008/109 and National Health Service Research & Development Department (See Appendix 1F and 1G for Ethical Approval letters from both the University and NHS Research Ethics Committee). An amendment was submitted to NHS Ethics and approved for the therapeutic study (See Appendix 1H).

7.4.2 Recruitment and inclusion criteria

Two children were recruited from a local education authority (See Chapter 4, Section 4.7 for details of record keeping and security, Appendix 1C for the Participant Information Letter and 1D for the consent form). Children were eligible for inclusion in the exploratory study if they met the following criteria:

Inclusion criteria

- under the age of 5 years (i.e. In Early Years Foundation Stage)
- Moderate, severe or profound hearing loss
- Substantial delays and poor development in spoken language learning as identified by their teacher of the hearing-impaired
- Children must have been fitted with hearing aid or cochlear implant by the age of 2;6
- Speech is their primary mode of communication

Exclusion criteria

- Known additional impairments
- Proficient sign language user

7.5 Participants

The participants were two children with congenital, profound bilateral sensorineural hearing loss. Each child wore a unilateral cochlear implant and did not make us of a hearing aid in their un-implanted ear. At the beginning of the study, the children were both attending mainstream Nursery provision within primary school settings. The children received five visits a week visits from either a teacher of the hearing-impaired or a support assistant specializing in hearing impairment who worked in collaboration with the teacher of the hearing-impaired. The details of the background characteristics and most recent audiological assessment regarding the children are presented in Table 7.2 and Table 7.3. The audiological information is limited due to the digitization of health and educational records, whereby only a limited amount of information is held over time. Therefore no data were available for pre-implant hearing levels or hearing levels in the un-implanted ear.

Table 7.2 ***Background characteristics of the children***

Child	Gender	Device	Age when CI fitted	Chron. Age (CA) at beginning of the study	Hearing Age (HA) at the beginning of the study	Access to Spoken Language from 250Hz-4000Hz wearing CI
Child X	Female	Unilateral CI	22 months	4;6	32 mos.	Yes
Child Y	Female	Unilateral CI	15 months	4;2	35 mos.	Yes

+ Both children's educational environment was a mainstream primary school

Table 7.3 ***Audiological information of children using their cochlear implant***

Child	Implanted Ear	250Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	6000 Hz
Child X	Right	25	25	25	25	25	25
Child Y	Left	35	30	35	30	35	30

Note: Hearing levels are in dB HL

7.6 Procedure

Staff Training

As part of the therapeutic programme, teachers of the hearing-impaired were provided with training regarding the theoretical and evidenced based reasoning behind the intervention, as well as the evidence base regarding difficulties that children with hearing impairment encounter (See Chapter 6, Section 6.9.5; Section 7.3 above and Figure 7.1). Case-based video examples were utilized in the training of staff as a way in which to enable a clearer understanding of the programme. The training also included observation of the techniques and strategies being utilized in the sessions with children with hearing impairment at different stages of their development. Teaching staff were encouraged to discuss how this approach to developing spoken language differed from their practice with other children with hearing impairment who follow typical language development and meet expectations regarding their progress.

Intervention

Each child' teacher of the hearing-impaired or specialist support assistant in hearing impairment (SSA) provided daily 1:1 intervention four to five mornings per week with both children in the study in their own school setting following the programme and recording the outcomes. The sessions varied in length from 45 minutes to 60 minutes per day and targeted key vocabulary, as identified in Section 7.3 above. The researcher observed the children in their own schools working with their teacher of the hearing-impaired for an entire one hour session after four weeks, three months, nine months and one year after the initial visit. (See sample session plans are in Appendices 14 and 15). The researcher also participated in the sessions, as a way in which to model the principles listed above and memory strategies mentioned previously in Section 7.3 (See Chapter 3, Section 3.7.1 for in-depth discussion). When appropriate, the researcher modelled strategies with the child for encouraging meaningful use of the targeted spoken language. The teacher of the hearing-impaired and the SSA attended follow up meetings with the researcher after the observations of the sessions for the purpose of discussing the sessions and addressing any difficulties or questions that they might have. The sessions were digitally recorded and were given to the teacher of the hearing-impaired, the SSA and the family. The video was utilized as a way in which to reinforce the methods and approach of the therapeutic programme. Parents were invited to therapy sessions in order to allow direct observation and participation of the sessions, as well as communication with the researcher. The participants' baseline of abilities and progress were evaluated using the Monitoring Protocol for Deaf Babies and Children (Department for Education and Skills, 2006). This tool is utilized with both children in the exploratory study as a way in which to evaluate progress in key developmental areas. The children's progress was also assessed at the end of the study using the MacArthur-Bates Communicative Development Inventories (MacArthur-Bates CDI) (Fenson et al., 2007).

7.6.1 Assessments

Monitoring Protocol for Deaf Babies and Children

The Monitoring Protocol for Deaf Babies and Children (Department for Education and Skills, 2006) is commonly used by teachers of the hearing-impaired in the UK to monitor developmental progress in children with hearing impairment in the first three years after identification of their hearing loss. The Monitoring Protocol for Deaf Babies and Children also supports parents in their understanding of their child's abilities and makes use of their observations regarding their child. It is developmental in its structure and allows professionals and parents to evaluate progress and plan future aims. However, there are limitations with the Monitoring

Protocol, in that it does not provide standard scores and different professionals may interpret the instructions in different ways, as the wording is not particularly specific. Therefore, children cannot easily be compared with normally hearing children or other children with hearing impairment. The Monitoring Protocol should be used with caution as the single measure to evaluate progress, and preferably alongside a standardized assessment such as the MacArthur-Bates CDI (Fenson et al., 2007). The Monitoring Protocol is comprised of five areas: communication, attending and listening, social-emotional development, play and other developmental milestones. A summary of the Monitoring Protocol is outlined in Tables 7.4 and 7.5 (See Appendix 13 for a more comprehensive version).

Table 7.4 ***Monitoring Protocol for Deaf Babies and Children stages B5 to B7***

Stage 5	Stage 6	Stage 7
Receptive	**Receptive**	**Receptive**
Understands some names of common objects	Comprehends at least 15 words	Comprehends more words each week and understands familiar words in new contexts
Stops when he/she hears "No"	Comprehends simple questions or commands e.g. Where is the ball	Comprehends face parts and will select a familiar object when asked
Expressive	**Expressive**	**Expressive**
Imitates and uses voice spontaneously e.g. "bye bye," "go"	Vocalizes freely when playing, with some recognizable words	Uses a minimum of 10 words
Imitates symbolic noises e.g. "moo," "baa"	Uses at least 5 words to express different meanings	Often uses favourite words/ phrases
Uses "Mummy" meaningfully	Uses language to request favourite game	Combines words with a gesture e.g. "Mummy" while pointing to a drink

The Monitoring Protocol states that:

Stage 5 represents an age equivalent of 9 to 12 months

Stage 6 represents an age equivalent of 12 to 15 months

Stage 7 represents an age equivalent of 18 months

Table 7.5 ***Monitoring Protocol for Deaf Babies and Children stages B8 to B11***

Stage 8	Stage 9	Stage 10	Stage 11
Receptive	**Receptive**	**Receptive**	**Receptive**
Comprehends many objects and pictures	Comprehends most common objects and pictures	Comprehends in, on, big, small, one, all	Comprehends more complex prepositions: under, behind, next to
Comprehends simple instructions or questions without additional gestures	Understands familiar verbs e.g. sit down, jump,	Comprehends simple questions e.g. "How old are you?"	Understands objects by description e.g. dirty, wet and pronouns e.g. he/she, they, him/her
Expressive	**Expressive**	**Expressive**	**Expressive**
Uses up to 20 words	Rapid growth in vocabulary- at least 50 words	Uses longer sentences now (i.e. 3-4 words)	Answers what, where and yes/ no questions
Begins combining words e.g. "mummy gone"	Use little sentences more frequently	Uses language to ask for help	Uses a range of verb forms e.g. play, played, playing
Words are more intelligible	Begins to use pronouns: me, I, you	Uses more than 200 words including: I, me, you, no, not,	Retells simple past events

The Monitoring Protocol states that:

Stage 8 represents an age equivalent of 18-21 months

Stage 9 represents an age equivalent of 21-24 months

Stage 10 represents an age equivalent of 30 months

Stage 11 represents an age equivalent of 36 months

The MacArthur-Bates Communicative Development Inventories

The MacArthur-Bates Communicative Development Inventories (MacArthur-Bates CDI) (Fenson et al., 2007) is a parental reporting assessment (i.e. checklist) that focuses on the early development of gestures, receptive and expressive vocabulary and early syntactic development (See Chapter 2, Section 2.4.1) and therefore complements the use of the Monitoring Protocol. The vocabulary checklist is organized in semantic categories, which enables parents to identify the words that their child understands and uses. This assessment is particularly sensitive to the early development of words. There are a limited number of assessments that are developed for very young children in the early stages of their language development. The MacArthur-Bates CDI is one of the few assessments that provides detailed information regarding specific vocabulary acquisition. It has also been utilized with children with hearing impairment to the extent that normative data regarding vocabulary development are available (Mayne et al.,1999a and 1999b; Chilosi et al., 2013, Moeller et al., 2007, Nicholas & Geers 2006 and 2013) (See Chapter 2, Section 2.4.1 for a detailed discussion of vocabulary assessments). Standard vocabulary assessments such as the British Picture Vocabulary Scale 2 were not suitable for the two children in the exploratory study, as the age range of the population on which it is standardized begins at age 36 months and their vocabulary abilities were not at this developmental level.

7.7 Child X

7.7.1 Baseline abilities

Child X was diagnosed with a profound hearing loss at 3 ½ months of age and fitted with binaural hearing aids at 4 ½ months. At the beginning of the study, Child X's chronological age was 4;6 and her hearing age was 2;8. She was able to identify pictures that related to the Ling Sounds which are "ah," "oo," "ee," "mm," "sh," and "s" (Ling, 1989). She was able to imitate these sounds through listening alone. Her functional level of spoken language use was extremely limited. No meaningful spoken language was observed through play, although her teacher of the hearing-impaired occasionally heard vocalizing.

The Monitoring Protocol (2006) was used by Child X's teachers of the hearing-impaired to evaluate her progress over time. At the beginning of the study, her language level, as identified by the Monitoring Protocol, was 15 months for receptive abilities and 12 months expressively (i.e. B6 to B7) (See Table 7.3 and Appendix 13). With regard to the three other areas examined by the Monitoring Protocol, Child X was functioning at 12 months for both attention and listening, and 9 months for vocalizing. At the beginning of the study, Child X was unable consistently to identify, through pointing or spoken language, sounds associated with objects, everyday objects/people, actions or face parts. However, she was able to express herself using the word "No." She was also able to turn to her name in quiet situations when she was not too absorbed in another activity.

The language input to Child X needed to be direct with overt exposures to a limited set of targeted vocabulary in a range of meaningful, pragmatically appropriate situations (See Section 7.3 for a discussion of the rationale, therapeutic principles and techniques). At the beginning of the study, the following aims were set in collaboration with her teacher of the hearing-impaired:

- Comprehension of 5 everyday objects and 5 everyday actions/requests within her school environment (see below)
- Comprehension of 2 sounds associated with objects e.g. up up up whee, round and round and round, and 5 early acquired words such as mummy, bye bye, all gone, more
- Development of appropriate pragmatic skills for school situations such as requesting and object and turn-taking

The initial vocabulary that was focused on comprised words from the child's everyday school or home routine such as snack-time and playtime. They included *milk, water, apple, banana, pear, coat, shoes, coat, toilet, my turn, wait, sit down, up up up whee, round and round and round, stop, my turn, go, and toilet*. The other vocabulary that was targeted later is presented in Table 7.1 and Figure 7.2.

7.7.2 Child X's progress

After three months of daily intervention, Child X was able to consistently comprehend and use sounds associated with objects such as "up up up whee" and "round and round and round," as well as everyday language, such as "milk," "apple," "my turn," "my turn," "sit down," "stop," "toilet," "wash your hands" and "help me." She also began using a small range of these words and phrases to communicate her needs spontaneously in her school environment. For example: "toilet," "mummy," "bye bye," "get out," "come on" (See Appendix 14, Table A for a sample session plan).

After nine months, Child X was able to comprehend two word phrases using familiar vocabulary through pointing to pictures and also use these simple sentences as a command to others. For example: "Mum apple;" "Child X Name banana;" "Child X Name bag." She was also able to comprehend and use the adjectives "big" and "small" in relation to an object such as a chair. (See Appendix 14, Table B for a sample session plan).

At the one-year point, Child X was also beginning to comprehend syntactic structures and/or phrases with three key words. For example: "Give me the <u>big blue ball</u>;" "Give <u>Mummy</u> the <u>shoes</u> and <u>coat</u>;" "Make the <u>dog jump</u> on the <u>bed</u>." Child X's use of single word vocabulary had increased to include animal names as well as the sounds, verbs and everyday questions (eg. "What is it?" "What is that?" "Where's ____?"). At this point, she began to combine words more spontaneously. She was able to generate phrases and multiword utterances such as: "Wash hands;" "Where's Child Name?" "Home sleep;" "My chair."

Assessment Results

MacArthur-Bates CDI

At the beginning of the study Child X's receptive vocabulary was age equivalent to normally hearing child aged 8 months and her expressive vocabulary was equivalent to a child aged 14 months. After one year of the implementation of the exploratory intervention programme, Child X's receptive score on the MacArthur-Bates CDI increased to 191 words, which is age equivalent to a child aged 16 months (See Figure 7.3). Her expressive score was 147 words, which is age equivalent to a child 21months of age (See Appendix 16 for a list of her expressive vocabulary from the MacArthur-Bates CDI). In order to assess the difference in her raw scores pre and post intervention, standard error of difference was calculated, $SE_{Diff} = sd * \sqrt{(2 - r_{xx} - r_{xx})}$ (Harvill, 1991). The standard error of difference was 77 words for receptive vocabulary and 118 words for expressive vocabulary. Therefore there was a statistically significant difference between Child X's pre and post scores at alpha.05, as the difference between her raw scores pre and post intervention were greater than 77 (receptive) and 118 (expressive) (See Figure 7.3).

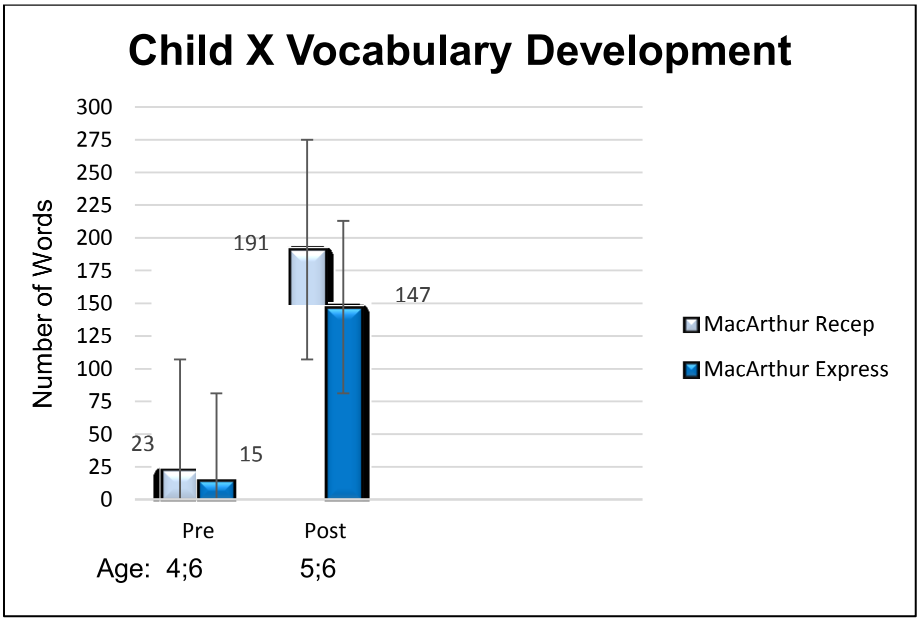

Figure 7.3 **Child X's MacArthur-Bates CDI Receptive and Expressive Vocabulary Development in Number of Words**

Monitoring Protocol

At the start of the study, Child X's receptive language was similar to a child age 15 months (i.e. receptive level of B6). After one year, the results of the Monitoring Protocol (See Tables 7.4, 7.5 and Appendix 13 for detailed information from the Monitoring Protocol levels) showed that her functioning was similar to that of a child aged 24 months (i.e. B9/B10). The results of the Monitoring Protocol demonstrated that Child X had developed from her initial expressive level of B5/B6 to B8/B9 (i.e. 12 months to 21 months).

Table 7.6 ***Child X's language development over the course of the study***

	Monitoring Protocol (MP) Receptive	**MP Expressive**	**MP Attention**	**MP Listening**	**MP Vocalizing**
Start: AE* **CA 4;6** **HA 32 mos**	15 months (i.e. B6)	12 months (i.e.B5-early B6)	9-12 months (i.e.B5)	9-12 months (i.e. B5-early B6)	9 months (i.e.B4-B5)
After 3 months* **CA 4;9** **HA 35 mos**	18 months (i.e. B7)	12-15 months (i.e. B6- a few B7)	12 months (i.e.B5-early B6)	12 months (i.e.B6)	12 months (i.e.B6)
After 1 year* **CA 5;6** **HA 44 mos**	24 months (i.e.B9, some B10)	21 months (i.e.B8-B9)	30 months (i.e.B9, some B11)	24 months (i.e.B9, some B10)	24 months (i.e.B9, some B10)

*AE = Age equivalent in months

To summarize, Child X began the study with less than 15 words in her expressive vocabulary after 32 months of cochlear implant use. After one year of daily multiple exposures to target vocabulary, her expressive vocabulary grew to 147 words (i.e. age equivalent to a child of 21 months). The trajectory of her vocabulary development changed from extremely limited progress initially with her cochlear implant (i.e. in the first 32 months of her use) to steady progress after the implementation of the exploratory intervention study. That is to say that at the beginning of the study Child X's receptive vocabulary had developed to a level equivalent to that of a normally hearing child aged 8 month and her expressive vocabulary was at a similar level to a child aged 14 months. This vocabulary development occurred after 32 months of cochlear implant use. After 12 months of the implementation of the exploratory programme, Child X had increased her receptive vocabulary by approximately 8 months and her expressive vocabulary by 7 months. Her development, as monitored by the Monitoring Protocol, also demonstrates that Child X developed approximately 9 months of receptive and expressive language after one year of the implementation of the intervention (See Table 7.6). She also increased her listening and vocalizing by 12 months and her attention by 18 months. While Child X did not develop 12 months of vocabulary or language over the 12 month duration of the study, there was considerable change in her rate of development since the implementation of the programme, given that after 32 months of cochlear implant use she was functioning between 8 and 15 months (See Table 7.6). With regard to her pragmatic abilities, such as turn-taking in a conversation and listening while others speak, the teacher of the hearing-impaired reported that Child X developed to a more appropriate level for her chronological age, as she was now able to participate with her peers during small group activities within the classroom. She also began to express her thoughts and needs spontaneously.

7.8 Child Y

7.8.1 Baseline abilities

Child Y was diagnosed with a profound hearing loss and at the age of 3 months, and fitted with binaural hearing aids at 3 ½ months. At the beginning of the study, Child Y's chronological age was 4;2 and her hearing age was 2;11. She was able to identify the Ling Sounds (e.g. "ah," "oo," "ee," "mm," "sh," and "s") through pointing to the correct picture that corresponded to the sound (e.g. "ee" was a picture of a mouse or "ah" was a picture of an airplane) and was able to imitate these sounds correctly through listening alone. She used single words, everyday learned phrases (e.g. my turn, all gone, wash hands) and gestures to express herself. Child Y was very quiet within the school environment but more vocalizations were heard when she was playing. Her expressive vocabulary consisted of early-acquired words such as “mummy,” “no,” “more,” “sit down,” “push,” “go,” animal sounds, face vocabulary, and her name. At the beginning of the study, Child Y was at level B8-B9 which is equivalent to a normally hearing child aged between 18 and 21 months (See Table 7.5). Initially, the following aims were set in conjunction with her teacher of the hearing-impaired:

- Increase receptive and expressive vocabulary by 20 words or phrases focusing on everyday object words and meaningful phrases (e.g. drink, milk, shoes, coat, wait, my turn, stop, push, toilet, wash your hands, and hold on).
- Expressive use of 5 words using known vocabulary in order to meet her needs.
- Increase her comprehension of school related vocabulary by 5 objects (e.g. bag, coat, and hat).
- Develop her comprehension and use of “Where?” in meaningful play situations

7.8.2 Child Y’s progress

After three months, Child Y was able to comprehend phrases with two key words. For example, “Child Y’s name” and coat or “Teacher’s name” and shoes. She was also able to comprehend two familiar everyday objects such a bag and coat or ball and baby. The following are examples of words that she was able to comprehend: animal names (e.g. pig, sheep, cow, dog, cat, and duck), a range of food vocabulary (e.g. milk, juice, apple, and orange), pronouns (e.g. me, you), verbs (e.g. jump, run, kick, cry) and question words (e.g. Where). (See Appendix 15, Table A for a sample session plan).

After nine months, Child Y was able to comprehend and use a repertoire of everyday words, including more verbs (e.g. brush, cut), adjectives (e.g. big, little, good, and colours) and prepositions (e.g. in, out, under). (See Appendix 15, Table B for a sample session plan).

After one year, Child Y was able to answer basic questions such as “Is it big?” or “Where is your bag?” Her receptive vocabulary had increased to include a wide variety of everyday objects, actions and phrases. Child Y was able to comprehend three key words using familiar vocabulary. For example, “Put the baby under the table” or “The girl ate an apple.” Child Y’s spontaneous language included an increased number of everyday phrases (e.g. dinnertime, playtime), everyday objects and actions (See Table 7.1 and Figure 7.2), as well as the following:

Pronouns: I, me, you, your

Question forms: What, Where

Descriptive words: bad, naughty big, little, wet, dry, dirty and colours

Emotion words: sad, happy

Irregular past tense verbs: broken, fell

Child Y was consistently using two and three word utterances. The following are examples of some of her utterances:

“Look, new boots!”

“Where my bag?”	“Hold my hand.”
“Where Miss____, there?”	“No running!”
“Mummy home.”	“My bed small.”

“I don’t like ice-cream.”

Assessment Results

MacArthur-Bates CDI

At the beginning of the study Child Y had a receptive vocabulary of 42 words which is age equivalent to a normally hearing child, as measured by the MacArthur-Bates CDI, aged 10 months and an expressive vocabulary of 35 words which is equivalent to a child aged approximately 15 months. After one year, Child Y’s receptive vocabulary was 294 words, which is age equivalent to a normally hearing child aged 18 months. Her expressive vocabulary was 243 words, which is age equivalent to a normally hearing child aged 22 months (See Figure 7.4

below and Appendix 17 for a summary of her expressive vocabulary from the Macarthur-Bates CDI). In order to assess the difference in her raw scores pre and post intervention, standard error of difference was calculated, $SE_{Diff} = sd * \sqrt{(2 - r_{xx} - r_{xx})}$ (Harvill,1991). The standard error of difference was 80 words for receptive vocabulary and 146 for expressive vocabulary. Therefore there was a statistically significant difference between Child Y's pre and post scores at alpha.05, as the difference between her raw scores pre and post intervention were greater than 80 (receptive) and 146 (expressive) (See Figure 7.4).

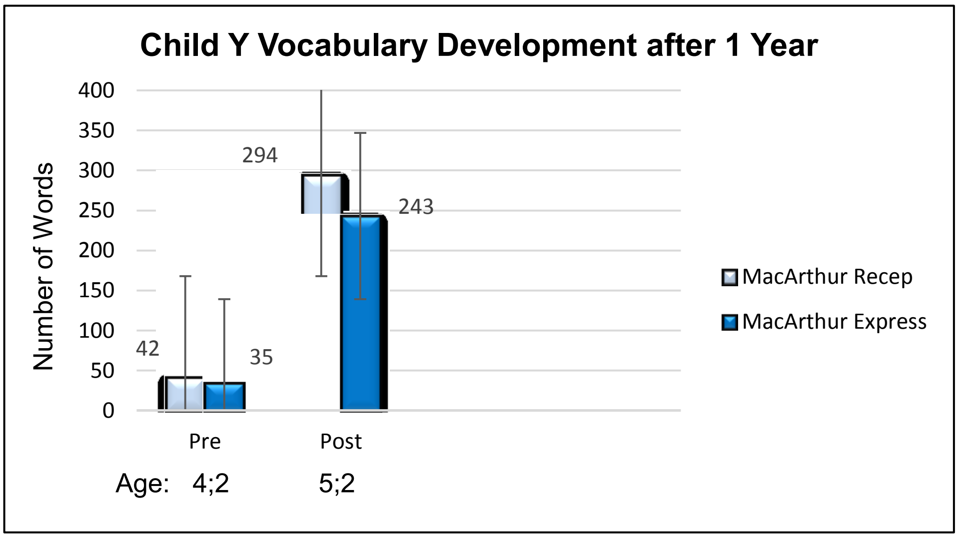

Figure 7.4 **Child Y's MacArthur-Bates CDI Receptive and Expressive Vocabulary Development in Number of Words**

Monitoring Protocol

At the start of the study, Child Y's receptive language was similar to a child aged 18-21 months (i.e. receptive level of B8-B9). After one year, the results of the Monitoring Protocol showed that her functioning was similar to that of a child aged 36 months (i.e. B11). The results of the Monitoring Protocol demonstrated that Child Y had developed from her initial expressive level of B8 expressively (i.e. 18-21 months) to a functioning similarly to a child aged between 30 to 36 months

(See Tables 7.5 and Appendix 13 for detailed information from the Monitoring Protocol levels).

Table 7.7 ***Child Y's language development over the course of the study***

	Monitoring Protocol Receptive	**MP Expressive**	**MP Attention**	**MP Listening**	**MP Vocalizing**
Start AE* **CA 4;2 (50 mos)** **HA 35 mos**	18-21 months (i.e.B8-B9)	18-21 months (i.e. B8)	21-24 months (i.e.B9)	21-24 months (i.e.B9)	21-24 months (i.e.B9)
After 6 months* **CA 4;8 (56 months)** **HA 41 mos**	30 months (i.e. B10)	30 months (i.e. B10)	30 months (i.e. B10)	30 months (i.e. B10)	30 months (i.e. B10)
After 12 months* **CA 5;2 (62 months)** **HA 47 mos**	36 months (i.e. B11)	30-36 months (i.e. B10-B11)	36 months (i.e. B11)	36 months (i.e. B11)	36 months (i.e. B11)

* AE = Age equivalent in months

In summary, after twelve months of daily, explicit exposure to new vocabulary, Child Y increased her expressive vocabulary to 243 words. This is in sharp contrast to the 35 single words that Child Y used when she began the study. The trajectory of her vocabulary development changed from extremely limited progress initially with her cochlear implant (i.e. in the first 35 months of her use) to steady progress after the implementation of the exploratory intervention study. That is to say that at the beginning of the study Child Y's receptive vocabulary had developed to a level equivalent to that of a normally hearing child aged 10 months and her expressive vocabulary was at a similar level to a child aged 15 months. This vocabulary development occurred after 35 months of cochlear implant use. After 12 months of the implementation of the exploratory programme, Child Y had increased her receptive vocabulary by approximately 8 months and her expressive vocabulary by 7 months. While Child Y did not develop 12 months of vocabulary over the 12 month duration of the study, she did appear to develop 7 to 8 months of vocabulary. This is a considerable change in her rate of development since the implementation of the programme, given that after 35 months of cochlear implant use her vocabulary development had only achieved a level equal to that of a normally hearing child aged between 10 and 15 months (See Figure 7.4). Her development, as monitored by the Monitoring Protocol, also demonstrates that Child Y developed approximately 12-18 months of receptive and expressive language after one year of the implementation of the intervention. She also increased her listening and vocalizing by 12-15 months and her attention by 12-15 months (See Table 7.7). This is a considerable improvement from her initial language abilities, as estimated by the MP, at approximately 18 to 21 months (i.e. B9 to B10) to 30-36 months (i.e. B10 to B11) by the end of one year (See Table 7.4, 7.5 and Appendix 13 for a detailed description of these levels from the Monitoring Protocol). Her conversational interactions improved to the extent that when asked by her teacher to "Please turn on the lights?" Child Y answered, "No, don't want to." She instead pointed to the teacher's bag and asked "Your red bag?"

7.9 Discussion

The aim of the study was to explore whether specific intervention, targeting word learning and vocabulary acquisition, is associated with changes in vocabulary or spoken language development. The intervention focused on two young children with hearing impairment who experienced considerable difficulties in developing spoken language. The vocabulary and memory findings from the current longitudinal study alongside the evidence base in the literature regarding weaknesses in verbal short-term memory, novel word learning, vocabulary deficits and the development of greater semantic knowledge and lexical organization were employed in the derivation of the programme of intervention.

7.9.1 Vocabulary and language development

The initial findings from the exploratory study suggest that the children with hearing impairment may benefit from longer experiences of new vocabulary via direct, explicit exposure as a way in which to develop vocabulary and enhance language learning. Their comprehension abilities also appeared to improve from the start of the study, when both children were only able to comprehend single items after more than 2 ½ years of cochlear implant use. After one year, Child X was able to comprehend consistently two word phrases (e.g. "Get your coat and shoes") and Child Y was able to understand three word phrases (e.g. "Mummy is cutting the paper"). Both children in the study made progress in their receptive and expressive language development, as evaluated by the Monitoring Protocol for Deaf Babies and Children. Both children in the study made substantial gains in their expressive vocabulary over the course of the study. Child Y's expressive vocabulary increased from approximately 35 words to 243 words. Child X's expressive vocabulary increased from 15 words to 147 words. As Child X had still not reached at critical mass of expressive vocabulary (i.e. approximately 200 words), she may continue to require explicit exposure to new words in order for her to carry on making progress. Child Y, however, has surpassed this point, but may also require this intensive input due to her initial difficulties in vocabulary development. The children's expressive vocabulary development cannot be compared with other studies that utilize the MacArthur CDI/MacArthur-Bates CDI such as Nicholas and Geers (2008) or Mayne et al. (1999b), due to their chronological ages at the end of the present research being greater (i.e. 5;2 and 5;8 years) than the children in the previously mentioned studies.

As the children in this current study display additional language learning difficulties, they may also require explicit input for a longer time in order for them to make a transition to a more indirect way of word learning. A further reason for prolonging the direct explicit exposure of new vocabulary for these children is that they do not benefit, to the same extent, as their normally hearing peers do from incidental “word learning” situations within the classroom environment or a social situations.

Pattern of vocabulary development

The two children in the exploratory study exhibited greater age equivalent scores in expressive vocabulary than receptive, both at the beginning and end of the study. This pattern mirrored the children with hearing impairment in the longitudinal study and is a pattern commonly observed by other researchers (Caselli et al., 2012; Chilosi et al., 2013; Geers et al., 2009; Geers and Nicholas, 2013; Nicholas and Geers, 2013). At the completion of the study, the results of the MacArthur-Bates CDI demonstrated that the two children in the intervention study displayed a pattern of word learning, which included a greater proportion of verbs, adjectives and question forms than nouns, which is different from that of normally hearing children. These two children’s word learning profiles were similar to the proportions observed in adult speech. Others in the field of hearing impairment have observed this pattern of vocabulary development, using the MacArthur-Bates CDI (Edwards, 2004; Willis and Edwards, 1996). This difference, to some extent, may be attributable to the communication needs of the children in the exploratory study being different from chronologically younger children in the MacArthur-Bates CDI normative sample. The children in the exploratory study are older and therefore are at a different cognitive level and have different needs and interests than those of younger children.

The words targeted in the intervention programme initially focused upon nouns. However, there was a small proportion of verbs, adjectives and question forms targeted due to the educational demands and functional needs of the children with hearing impairment, as these types of words are more useful for children of this age than a larger proportion of nouns. That is to say, even though the two children’s vocabulary levels in this study are approximately equal to that of normally hearing children aged between 20 to 22 months, their ideas and interests are more in line with their chronological ages of 5;2 and 5;8. Thus, a needs-led pattern has developed individual to these children with hearing impairment, because of their different chronological age, in relation to the normative population from the MacArthur-Bates CDI. The clinical relevance of these findings suggest that support teams need to make use of the MacArthur-Bates CDI, both as an assessment tool but also as a way in which to monitor the specific words that a child is learning and using in their everyday environment. The repeated use of the MacArthur-Bates CDI will also enable the evaluation of the rate of vocabulary growth, as well as inform aims for intervention. The use of this assessment alongside the careful monitoring of other vocabulary that is targeted, because of educational demands and interests, allows for comprehensive monitoring of vocabulary development for these children.

7.9.2 Creation of robust representations

The focus of the intervention for the two children in the exploratory intervention was to target a specific small set of vocabulary as a way in which to create greater semantic knowledge and clearer phonological and lexical representations. The increased semantic knowledge surrounding a word was introduced by using pictures of targeted words and relating them to words within the same semantic category (See Table 7.1 and Figure 7.2). This "deep knowledge" of words was also facilitated by the teacher of the hearing-impaired and the support staff using the same vocabulary throughout the school day when interacting with the children (See Section 7.3). This included silent sorting of objects within the same semantic category, creation of semantic networks through the use of pictures and linking new vocabulary items with familiar items. The initial findings from the programme of intervention should be interpreted with caution. They do, however, suggest that young children with hearing impairment who are at risk of delayed vocabulary and language development may possibly benefit from the type of intensive structured input that the current programme of intervention provided. The clinical application of such a therapeutic programme may not only benefit children with hearing impairment who display LLD, but also children with hearing impairment in the initial stages of their language development who are fitted with their equipment late or are inconsistent users of their hearing aids or cochlear implants.

7.10 Summary of the findings from the exploratory intervention study

The findings from the exploratory intervention study tentatively suggest that the intensity and type of language exposure (daily and in a direct manner), alongside the initial targeting of a small group of contextually functional words enabled these two children with hearing impairment with LLD to begin to acquire vocabulary more quickly. This process has possibly also facilitated their ability to comprehend two and three word phrases, as well as combine familiar words into simple sentences. The findings from the current exploratory study could suggest that the creation of richer semantic networks using the techniques mentioned above and visual support in the form of pictures and objects supported the development of clearer, better-defined representations. A possible interpretation of the results is that this programme may have facilitated better lexical organization as new vocabulary was introduced in a systematic manner (See Table 7.1 and Figure 7.2), thus enabling a more efficient process of word storage and the acquisition of new vocabulary items. Application of the programme to a larger group of children would help to confirm or reject this interpretation.

7.11 Limitations

The two children who participated in the exploratory study were recruited through opportunity sampling. As there are only two participants, the study can only be presented as an exploration of a therapeutic approach; the findings from the therapeutic study are limited to these two children. The outcomes for other children with hearing impairment and considerably delayed language development may provide different results. However, these two children are not atypical in their characteristics (i.e. age of identification and orally educated). Therefore, the results from the study tentatively propose that the intervention is worthy of consideration in the future management of children with hearing impairment at risk of poor spoken language outcomes. As noted above, there is a need for larger scale evaluation of the intervention approach in order to inform evidence-based practice. The use of assessments such as the MacArthur-Bates CDI and Pre-school Language Scales to monitor children's progress in a multiple baseline study may provide the evidence that is required to inform clinical practice with children with hearing impairment and LLD.

An additional factor to be considered is the age of the children. If the programme of intervention had been implemented with the children when they were younger (i.e. 2;6 or 3;2 instead of 4;2), would their results be different? It is uncertain to what extent the children's previous language learning experiences, prior to the exploratory intervention programme, has influenced their progress. The results suggest that there were gains in receptive and expressive vocabulary and language learning and that there has possibly been a change in these children's trajectory of language learning (See Sections 7.7, 7.8 and Figures 7.3 and 7.4).

7.12 Application to clinical practice

The findings in the current study could assist in the development of specific programmes of interventions that may remediate the early word learning difficulties and vocabulary deficits that a proportion of children with hearing impairment experience. It would seem preferable that the programme to be implemented through training parents in the principles as soon as it becomes apparent that the child is having difficulties with word learning and therefore exhibiting slow progress. Researchers have shown that is difficult for children with hearing impairment to "close the gap" and achieve age appropriate spoken language once children are delayed in their language development (Geers et al., 2009; Yoshinago-Itano et al., 2010). This programme utilized the strengths in visual memory by incorporating the use of pictures and objects to support word learning, increased semantic knowledge, lexical organization and the development of robust phonological and lexical representations. The regular monitoring of vocabulary development using the MacArthur-Bates CDI is also a useful way in which to identify the gaps in vocabulary acquisition with regard to specific semantic categories. It would be beneficial for professionals and families to utilize other standardized assessments such as the Pre-school Language Scales-5 (Zimmerman et al., 2015) alongside the Monitoring Protocol to enable a comparison between the children with hearing impairment and their normally hearing peers and children of the same hearing age.

7.13 Summary

The research objective of the exploratory intervention was to develop a theory driven intervention to pilot test the findings of the study. The aim of the exploratory intervention study was to investigate whether a therapeutic programme that focused upon early word learning, lexical organization and the development of greater semantic knowledge could influence changes in vocabulary and language development. This hypothesis was derived from the influences from contemporary literature and the current study's findings with regard to extremely poor vocabulary development and word recall abilities exhibited by the children in the case series. The results from this exploratory study offers limited but nevertheless optimistic evidence to suggest that the two young children may have benefitted from the programme of intervention, as there has been acceleration in their vocabulary and language learning. This preliminary intervention study is an innovative attempt at therapeutically addressing the poor spoken language outcomes in children with hearing impairment. The final chapter summarises the thesis and makes recommendations for the future based on the findings from the longitudinal and exploratory intervention study.

Chapter 8 Conclusion

8.1 Introduction

It is commonly acknowledged among practitioners and researchers in the field of hearing impairment that the earlier a child has access to auditory input via hearing aids or cochlear implants, the greater the likelihood that the child will acquire spoken language similar to their normally hearing peers (See Chapter 2, Section 2.7). However, even in ideal circumstances of early device fitting and intensive spoken language input, a proportion of children with hearing impairment will not acquire language equal to that of their peers, even after several years of support from their family and professionals. The variability in spoken language outcomes for children with hearing impairment provides one of the current debates in the field of hearing impairment. The present study investigated the population of children with hearing impairment who have not achieved age appropriate spoken language despite long term hearing aid or cochlear implant use and intensive input. The final chapter of this thesis will discuss the conclusions of the research study with a specific focus on the strengths and limitations of the study, the methodological considerations, the implications for future research in the field of hearing impairment and finally the practical application and theoretical implications of the thesis. The research questions was "What is the developmental profile and trajectory in vocabulary, language and memory for children with hearing impairment who exhibit language learning difficulties?" The aim of the current research was to investigate factors associated with vocabulary and language development in this cohort of children. Three objectives were identified in order to achieve the aim and answer the research question.

8.2 The research objectives

Vocabulary, language and memory abilities were examined in six children with hearing impairment and additional language learning difficulties (LLD) annually across three time points. The research objectives were:

1. To profile memory, vocabulary and language development within a longitudinal study.
2. To investigate what aspects of vocabulary, language and memory are impacting upon the development of these children
3. To develop a research and theory-driven intervention to pilot test the findings of the study

The intention of the thesis was to add to the very limited research base relating specifically to this cohort of children with hearing impairment.

8.3 Conclusions

Vocabulary and language abilities

This research is the first known study to investigate the population of children with hearing impairment and LLD longitudinally. The findings from the study indicate that this cohort of children are following the same pattern of vocabulary development as other children with hearing impairment, in that their expressive vocabulary abilities are in advance of their receptive vocabulary. However, they are considerably delayed in their development of both receptive and expressive vocabulary in relation to normally hearing children and their peers with hearing impairment. The children in the study also exhibited extremely poor grammatical and syntactic development for their chronological age. Difficulties in these areas of development are typical for children with hearing impairment due to their perceptual difficulties. However, the present study group displayed expressive language difficulties that were more extreme and appear to have shown limited improvement over time. It is hypothesized that the interaction between the children's poor quality phonological and lexical representations, in conjunction with limited vocabulary and semantic knowledge combined to create extreme difficulties in word learning and the pervasive deficits found in their spoken language development.

Memory abilities

The present study utilized a battery of memory assessments that previously, other researchers in the field of paediatric hearing impairment have not used. Many researchers have attributed differences in spoken language development to slower verbal rehearsal speed, and poorer verbal short-term memory (as measured by Digit Recall and traditional Non-word Recall tasks) and working memory abilities (as measured by Backward Digit Recall tasks). While these tasks demonstrate that, some children with hearing impairment are poorer at these tests, these children's specific difficulties may not be apparent as Digit Recall and multisyllabic Non-word Recall tasks rely on underlying skills and proficiencies (See Chapter 6, Section 6.9.1). The findings from the current study tentatively suggest that the children with hearing impairment and LLD have difficulties in the storage of words and accessing the long term memory because of inadequate phonological and lexical representations. They do not appear to display deficits in processing or to exhibit generalized difficulties across both verbal and visual domains. Their deficits are restricted to verbal short-term memory with specific reference to the poor ability to access, recall and store words, which required robust phonological and lexical representations alongside substantial semantic knowledge.

Therapeutic programme

The findings from the exploratory intervention suggest that children who exhibit poor word learning abilities and/or substantial LLD may benefit from targeted intervention that specifically focuses upon increased exposure to direct word learning for a longer duration. This intensive exposure to words alongside the creation of greater semantic knowledge, lexical organization and more well defined phonological and lexical representations may enable the acquisition of new words at a faster rate.

8.3.1 Strengths

The current study examined a cohort of children with hearing impairment and additional language learning difficulties. There is a very limited evidence base in the literature concerning the long term vocabulary, language and memory abilities of these children. Other researchers have not previously discussed the memory and language results illuminated in this thesis, with regard to the subgroup of children with hearing impairment who display long-term difficulties in spoken language learning. The creation of memory profiles utilizing multiple verbal and visual memory tests is novel for this population of children. The knowledge gained from evaluating this cohort may provide answers as to why some children with hearing impairment achieve more age appropriate spoken language and some do not. The longitudinal design of the study along with the participant's characteristics, of early device fitting, communication mode and age, suggests that study's findings could be of relevance to many orally educated children with hearing impairment and additional LLD. The research benefitted from assessment information collected annually from educational reviews, and meetings with speech and language therapists and educational support teams. This information, alongside the language and memory scores obtained from the longitudinal study, enabled an in-depth examination of the six children's present language abilities and a greater understanding of their development throughout as well as insight into their early development prior to the beginning of the study. Their early difficulties in word learning and combining words were mirrored by those of the children in the exploratory intervention study. The use of a range of receptive and expressive vocabulary and language assessments allowed for the comprehensive evaluation of receptive and expressive abilities and the identification of possible patterns of development and change over time. The case series study also investigated both verbal and visual memory abilities utilizing a different battery of assessments, which has enabled the development of memory profiles for this group of children with hearing impairment and LLD. The implementation of present study's findings into a therapeutic programme is novel and may provide a basis for a more rigorous evaluation of the intervention approach, as well as encouragement for other researchers to explore different programmes of intervention in children with hearing impairment.

8.3.2. Limitations

As mentioned previously, one of the limiting factors from the study includes the role of the researcher as the single administrator of the assessments in the longitudinal study, thus introducing a source of bias. An additional limitation may be the small sample size of the longitudinal study and the exploratory intervention study (also see Chapter 4, Section 4.3, Chapter 6, Section 6.8 and Chapter 7, Section 7.1.1 for a discussion of other limitations). The present study also does not allow for the evaluation of literacy abilities with regard to the six children who participated in a longitudinal study. This information may be useful in future research, as a way in which to identify the educational impact of language delay and weaknesses in verbal short-term memory abilities. The framework for the assessment and understanding of the children's memory abilities is based entirely upon Baddeley's Working Memory Model (2003). This is the most widely used model of working memory and therefore the outcomes from this thesis can be compared with those of other researchers who have used this model. However, the use of the capacity theory (Just and Carpenter, 1992; See Chapter 3, Section 3.2) may have provided additional reasons and justification for strengths and weaknesses in verbal and visual short-term memory and working memory. These explanations would potentially focus upon the relationship between storage and processing and that the difficulties that the children with hearing impairment and LLD exhibit are related to increased demands in either memory or processing. An alternative way in which to explain this would also state that these children have a more limited pool of resources from which to draw upon and therefore their overall capacity in both storage and processing is reduced. The capacity theory would not allow for a separate examination of verbal and visual memory abilities and therefore one would assume that these children with LLD children have generalized memory abilities that are poorer than their normally hearing and hearing-impaired peers. However, there is no evidence to state that the children in the case series exhibited deficits in processing which relates to the functioning of the central executive. The usefulness of Baddeley's model is that it clearly distinguishes, and separates, the functioning of systems such as the phonological loop, visuo-spatial sketch pad, the episodic buffer, and the central executive (which co-ordinates processing across both visual and verbal modalities).

8.4 Methodological considerations

Studies in the field of hearing impairment and memory abilities have frequently utilized similar tests to each other to measure verbal short-term memory and working memory. The present study made use of different memory assessments, which make it difficult to make direct comparison with the findings of other researcher studies (See Chapter 6, Section 6.5). That said, the findings from the present study provide a new avenue for other researchers to explore when investigating the memory abilities of children with hearing impairment. The thesis did not include an assessment of verbal rehearsal speed as part of the battery of assessments evaluating memory abilities; this evaluation of verbal rehearsal may have provided additional useful data. However, as many teachers of the hearing-impaired and speech and language therapists use rehearsal strategies as part of their therapeutic and educational input, this practice may have had an impact upon the children's results.

8.5 Directions for future research

Over the past three decades, researchers have focused on developing a body of knowledge in relation to the development of language in children with hearing impairment. Particular focus has been on children who use cochlear implants and those identified early, as part of the U.K.'s, U.S.A.'s and Australia's (amongst other countries) Newborn Hearing Screening Programmes. There is now substantial evidence that children with hearing impairment benefit from the use of cochlear implants although, perhaps more importantly, that early fitting of either hearing aids or cochlear implants does not ensure age appropriate language development. The current study is an innovative attempt at identifying patterns of language development and memory abilities in the subgroup of children with hearing impairment who experience additional difficulties in learning spoken language. There is a need for further research into this specific cohort of children with hearing impairment who continue to exhibit long-term deficits in spoken language development. However, the current research findings in relation to these children's trajectory of language learning and memory abilities has the potential to provide clinicians with the evidence that will inform their decision-making with regard to intervention, communication mode and educational placement.

It is recommended that research in the field of hearing impairment now needs larger studies that utilize a battery of memory assessments that allow for the comprehensive evaluation of different aspects of verbal and visual short-term memory and working memory abilities, thus creating memory profiles. The new knowledge created by using different tests may illuminate patterns of development and provide much needed answers in relation to verbal short-term memory, word learning difficulties and delayed vocabulary development in children with hearing impairment. A recommended goal of future research would be to investigate if there are different memory abilities or profiles of children with hearing impairment who achieve age equivalent spoken language by the age of 4;6 years compared with those children who have been unable to acquire language at a similar rate. The results gained from comparing these groups of children with hearing impairment may uncover whether the memory profile found by the present study is common to all children with hearing impairment or just the subgroup of children who exhibit LLD. The current case series targeted children with hearing impairment from a wide age range. Forthcoming studies may also benefit from focusing on children with hearing impairment within the same age range, as well as across ages. This would highlight developmental changes in memory abilities in children with hearing impairment and possible patterns of development that exist irrespective of chronological age. Additional longitudinal research over a longer timeframe, as a way in which to investigate children's development and *when and if* subsequent changes in language and memory abilities occur for children with LLD, is also warranted.

8.6 Practical applications

Researchers have found that children with hearing impairment have difficulty in overcoming the deficit between their chronological age and language age and that they are more likely to maintain the rate of language learning than close the gap (Geers et al., 2009; Geers and Nicholas, 2013; Nicholas and Geers, 2007; Yoshinaga-Itano et al., 2010). The findings from this thesis parallel those of other researchers who found that grammar and syntax are also areas that require on-going therapeutic input beyond the age of 4;6 (Caselli et al., 2012; Duchesne et al., 2009; Geers and Nicholas, 2013; Nittrouer et al., 2014; Szagun, 2001). The development and implementation of a therapy programme that can address the early word learning difficulties and delayed morphosyntactic abilities that the children in the current study experienced is a priority. The programme developed and trialled in the final part of this thesis goes some way to accomplishing this. It is not only the population of children with LLD in the present study that may benefit, but many other children with hearing impairment who are at risk of experiencing LLD because of late diagnosis of their hearing loss and/or inconsistent use of their hearing aids or cochlear implants. The exploratory intervention programme presented in this thesis is an initial attempt at addressing these important clinical issues and requires further exploration as a way in which to inform evidence based practice.

The findings from the present study should encourage professionals to utilize the MacArthur-Bates CDI or other comparable assessments regularly, in the early stages of vocabulary development. This may enable clinicians and researchers to examine the quantity and type of words that are being learned, as well as monitor the trajectory of children's progress. This would allow support staff to provide direct intensive word learning exposure for longer, based on the quantity of vocabulary learned. With regard to vocabulary acquisition, the findings from the exploratory intervention study call into question whether these children's range of vocabulary items (nouns, verbs, adjectives, questions forms) is typical of many children with hearing impairment or just those who are experiencing LLD. This pattern of word learning may in part be a result of the focus of intervention, as well as a different language learning experience. That is to say that children with hearing impairment do not learn incidentally, as normally hearing children do, as a result of their hearing impairment. Their language input is therefore different and often more "needs led." Thus, the words that these children are exposed to and learn do not always follow a typical age of acquisition sequence. If this hypothesis holds true for children with hearing impairment, then the clinical interpretation of frequently used vocabulary assessments, such as the British Picture Vocabulary Scale, warrants caution. Qualitative examination of the results from that assessment may only suggest that the vocabulary that children with hearing impairment learn is different from that of their normally hearing peers, and that the receptive vocabulary development in children with hearing impairment may not necessarily be as delayed as the literature suggests. It may also illuminate gaps in vocabulary development that could cause difficulties in educational settings.

8.7 Theoretical implications

This thesis is unable to answer the question as to why there is large variability in spoken language outcomes. However, it does provide a greater depth of understanding about that proportion of children with hearing impairment who exhibit substantial delays in language development after many years of hearing aid or cochlear implant use; in particular, those children with hearing impairment who also display weaknesses in word storage and retrieval. The findings from the thesis, in conjunction with future research, may allow researchers to move forward in their debate regarding the possible causes of the variability in spoken language outcomes for children with hearing impairment. That is to say, if future studies find that the majority of children with hearing impairment display similar profiles of verbal short-term memory and working memory as the current study group, and that this is a common denominator among children with hearing impairment, irrespective of proficiency in language learning, the questions asked by researchers will need to change. The children with hearing impairment and LLD exhibit a unique memory profile in relation to other children with developmental disorders. The interaction between this pattern and their deficits in vocabulary and semantic knowledge combine to create pervasive difficulties in word learning and morphosyntactic development. Alternatively, if it is found that the cohort of children with hearing impairment with age appropriate vocabulary and language display a different profile of memory abilities than those of children with hearing impairment and LLD, the conclusion that can be drawn is that specific differences in the quality of representations (e.g. as identified by the Word Recall task), adversely affect word storage and access. Therefore, this may be one of the key factors which is contributing to the variability in language outcomes. The innovative therapy programme indicated that early word and language learning could be enhanced and remediated to some extent by creating clearer representations through the use of greater semantic knowledge, lexical organization and visual support. In either case, the next stage in our journey to better support these children with hearing impairment will be to develop intervention programmes of support that will enhance their vocabulary and language learning based upon the research evidence. This process could evolve from small-scale intervention studies by speech and language therapists and teachers of the hearing-impaired focusing specifically on this population of children with hearing impairment who display substantial difficulties in spoken language learning. The collation of these findings would be a useful contribution to the evidence base, in addition to a larger scale evaluation of the intervention utilized in the exploratory study.

8.8 Concluding comments

As a result, of the Universal Newborn Hearing Screening Programmes in the developed world, many children receive a formal diagnosis of hearing loss prior to the age of three months. However, it is the adeptness with which carers can fit ear moulds and hearing aids, alongside the amount of daily hearing aid use, which will affect whether their child can access and potentially learn spoken language during infancy. Given the surgical implications and risks of cochlear implant surgery prior to six months of age, it is unlikely that the vast majority of profoundly deaf children will be able to receive a cochlear implant earlier than this point. It is speculated that the early deprivation of auditory information in the first six months of life and the impoverished signal from hearing aids or cochlear implants, will adversely affect the development of robust representations. Conversely, it may well be that age of implant or the duration of auditory experience may not be an added advantage in the development of well defined, phonological and lexical representations. Further research is warranted to provide the additional answers to the accuracy of this hypothesis, which if found to be correct, will mean that many more children with hearing impairment will be at risk of poor spoken language development than anticipated.

The development of memory profiles from this thesis support the assertion that the difference in the *quality of auditory input* and *auditory experience* that children with hearing impairment receive contribute to their difficulties in word storage, early word learning, lexical organization and language development. Therefore, the therapeutic ways in which we compensate for these differences in auditory development and listening experience are paramount. This thesis provides some evidence for additional ways in which to individualize therapeutic input for children with hearing impairment and poor spoken language outcomes, and enable researchers to consider other options alongside the use of memory training programmes.

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Appendices

Appendix 1: Invitation to Take Part Letter, Parent Information Letters and Consent Form, Ethics Approval Letters

Appendix 1A Invitation to Take Part Letter

Invitation to Take Part in a Research Study

Study Title- A longitudinal study of atypical language learners with hearing impairment and the perceived implications in educational settings

I would like to invite you to take part in a research study. Before you decide, you need to understand why the research is being done and who is conducting the research. Please take your time to read the following information carefully. Talk to others about the study if you wish. This research is taking place with children and adolescents from ____________ .

Why is this study being done?

Some children with a hearing loss develop language without any additional problems beyond the hearing impairment and "catch up" with their hearing peers after 4 years of hearing aid or cochlear implant use. Yet, other children have great difficulty in remembering new vocabulary and developing age appropriate grammar and sentence structures. I am interested in children and adolescents who are struggling to "catch up" and the possible reasons why. I want to find out what specific difficulties children and adolescents with a hearing impairment are having with their language development.

Who is in charge of the study?

The study is being carried out by Suzi Willis. I am an experienced speech and language therapist who has worked with children and adolescents who are hearing-impaired for the past 15 years. I work at Manchester Metropolitan University (MMU) as a lecturer. I will be carrying out this study as a PhD project and am being supervised by Professor Juliet Goldbart (psychologist) and Professor Jois Stansfield (speech & language therapist).

If you are interested in the study and would possibly like your child to take part, please read the attached Participant Information Sheet.

Thank you for your time.

Suzi Willis

Appendix 1B Parent Information Letter for Three Year Study

Study Title – A longitudinal study of atypical language learners with hearing impairment and the perceived implications in educational settings

I want to tell you about some research that I am asking your child or adolescent to take part in. This project has been passed by an independent Research Ethics Committee and by my university's Faculty Research and Enterprise Committee.

Your child's teacher of the hearing-impaired has identified your child as meeting the criteria for the research project. It is very important that you understand why the research is being done, what the research is about and what it would involve for your child. It is your decision whether your child takes part in the project.

What is the purpose of the project?

This research project is concerned with developing a better understanding of the kinds of language and memory difficulties that hearing-impaired children and adolescents have. The results from the project will hopefully allow for support that is better designed to meet the needs of hearing-impaired children who are struggling to develop language. The research project will ask the following questions:

- What are the language learning and memory difficulties that children with experience?
- How do these difficulties change?
- What strengths and weaknesses in memory abilities do children/adolescents with hearing impairment have?
- What are the perceived educational implications of their difficulties?

Why have I been asked to take part?

You are being invited to take part in this research because you have a child of adolescent with a hearing impairment between the ages of 6 and 16 years old who may be experiencing language learning and/or memory difficulties. Your child may find learning new vocabulary in school difficult and may also have difficulty remembering instructions.

Do I have to take part?

Taking part is entirely voluntary. If you wish to be involved you will be given an consent form to read. You can then meet the researcher and ask questions about the project. If you are happy for your child to participate, you can then complete and sign two consent forms, one of which you will keep and the other will be kept by me.

<u>You are free to withdraw at any time without giving a reason. This will not affect the standard of care your child receives</u>.

What if I decide to take part?

If you decide to take part in the study, you will need to contact me or your child's teacher of the hearing-impaired to tell us that you have decided to take part. You can do this by returning the attached reply slip, or using my phone number or e-mail address included in this leaflet. I will contact you within one week to arrange to meet you to discuss any questions you might have and for you to complete and sign the consent forms.

What will happen if my child/adolescent takes part in the project?

Your child will be seen for three sessions at school, where you may come and observe the sessions if you wish. Unfortunately, we are not able to reimburse your travel expenses. Each of the sessions will be no more than 45 minutes in length. During these sessions, the researcher will administer language and memory assessments to your child. Some of these assessments will be audio or video taped in order to allow me to focus more on your child and his/her responses. These assessments will be administered on an annual basis for three years.

What are the possible benefits/risks of taking part?

The assessments used with your child have been used for a long time with children and adolescents with and without language learning difficulties. There are no known risks associated with the assessments. Children and adolescents with hearing impairment may benefit from this project, as the outcome of the study may lead to a greater understanding of the difficulties that they have.

Who is responsible for the study?

The study is being carried out by Suzi Willis. I am an experienced speech and language therapist who has worked with children and adolescents who are hearing-impaired for the past 15 years. I work at Manchester Metropolitan University (MMU) as a lecturer. I will be carrying out this study as a PhD project and am being supervised by Professor Juliet Goldbart (psychologist).

Who will see my child's information?

All information from the study will be seen only by me and my research supervisors. The information from these assessments will be shared with you, as well as your child's local speech and language therapist and teacher of the hearing-impaired, **if** you give permission.

What happens with my child's test results?

- Your information will be kept anonymously; this means it will not have your child's name on it. When publishing or presenting the results of the study, your child's identity will be kept anonymous.
- All information including audio and video recordings will be anonymised and kept in a locked cabinet, in a locked office at Manchester Metropolitan University (MMU) for a period of five years. This will allow for the possibility a follow up study.
- Data analysis will be carried out on a password protected laptop computer on MMU premises. No identifiable personal information will be saved on the laptop.

What if I have a concern or complaint about the research study?

If you have any queries, concerns or complaints about any aspect of the study, please contact me, Suzi Willis. If you remain unhappy and wish to take the matter further, you may contact my supervisor, Juliet Goldbart. Our details are as follows:

I can be contacted at MMU by:

- Telephone: 0161 247 4639
- E-mail: s.willis@mmu.ac.uk
- Post: Suzi Willis, Speech & Language Therapist, Faculty of Health, Psychology & Social Care, Manchester Metropolitan University, Hathersage Road, Manchester, M13 0JA

My supervisor, Juliet Goldbart can be contacted at MMU by:

- Telephone: 0161 247 2578

- E-mail: j.goldbart@mmu.ac.uk
- Post: Professor Juliet Goldbart, Professor of Developmental Disabilities, Faculty of Health, Psychology & Social Care, Manchester Metropolitan University, Hathersage Road, Manchester, M13 0JA

If you remain unhappy and would like to discuss your concerns with someone who is independent of the project, you may also contact the Director of the Research Institute for Health and Social Change,

Carolyn Kagan. Her details are:

- Telephone:0161 247-2563
- E-mail: c.kagan@mmu.ac.uk
- Post: Professor Carloyn Kagan, RIHSC, Faculty of Health, Psychology & Social Care, Manchester Metropolitan University, Hathersage Road, Manchester, M13 0JA

What if I still have questions about the study?

If you would like to ask any questions or get more information about the study, I would be happy to speak with you. Please contact me using the details above on this page of the information sheet.

Thank you for your time.

Suzi Willis

Please fill in your child's name and initial the appropriate box.

Please return to this slip to your child's teacher of the hearing-impaired

---

I would like _______________ to participate in the research project ☐

I would **NOT** like_____________ to participate in the research project ☐

Appendix 1C Parent Information Letter for Intervention Study

Participant Information Sheet

Study Title – A longitudinal study of atypical language learners with hearing impairment and the perceived implications in educational settings

I want to tell you about some research that I am asking your child or adolescent to take part in. This project has been passed by an independent Research Ethics Committee and by my university's Faculty Research and Enterprise Committee.

Your child's teacher of the hearing-impaired has identified your child as meeting the criteria for the research project. It is very important that you understand why the research is being done, what the research is about and what it would involve for your child. It is your decision whether your child takes part in the project.

What is the purpose of the project?

This research project is concerned with developing a better understanding of the kinds of language and memory difficulties that hearing-impaired children and adolescents have. The results from the project will hopefully allow for support that is better designed to meet the needs of hearing-impaired children who are struggling to develop language. The research project will ask the following questions:

- What are the language learning and memory difficulties that children with hearing impairment experience?
- How do these difficulties change?
- What strengths and weaknesses in memory abilities do children/adolescents with hearing impairment have?

Why have I been asked to take part?

You are being invited to take part in this research because you have a child or adolescent with a hearing impairment between the ages of 3 and 16 years old, who may be experiencing language learning and/or memory difficulties. Your child may find learning new vocabulary in school difficult and may also have difficulty remembering instructions.

Do I have to take part?

Taking part is entirely voluntary. If you wish to be involved, you will be given a consent form to read. You can then meet the researcher and ask questions about the project. If you are happy for your child to participate, you can then complete and sign two consent forms, one of which you will keep and the other will be kept by me.

<u>You are free to withdraw at any time and without giving a reason. This would not affect the standard of care your child receives.</u>

What if I decide to take part?

If you decide to take part in the study, you will need to contact me or your child's teacher of the hearing-impaired to tell us that you have decided to take part. You can do this by returning the attached reply slip, or using my phone number or e-mail address included in this leaflet. I will contact you within one week to arrange to meet you to discuss any questions you might have and for you to complete and sign the consent forms.

What will happen if my child/adolescent takes part in the project?

Your child will be seen for three sessions over a 9-12 month period at the MMU clinic or school, where you may come and observe the sessions if you wish. Unfortunately, we are not able to reimburse your travel expenses. Each of the sessions will be no more than 45 minutes in length. During these sessions, the researcher will play with toys and interact with your child and their teacher of the hearing-impaired. These sessions will help the researcher to provide targeted input and support to help your child learn spoken language more easily.

What are the possible benefits/risks of taking part?

The type of toys (ie. Mr. Potato Head, Play Dough, PlayMobil® used with your child have been used for a long time with children and adolescents with and without language learning difficulties. There are no known risks associated with using these toys in a therapeutic way. Children and adolescents with hearing impairment may benefit from this project, as the outcome of the study may lead to a greater understanding of the difficulties that they have.

Who is responsible for the study?

The study is being carried out by Suzi Willis. I am an experienced speech and language therapist who has worked with children and adolescents who are hearing-impaired for the past 15 years. I work at Manchester Metropolitan University (MMU) as a lecturer. I will be carrying out this study as a PhD project and am being supervised by Professor Juliet Goldbart (psychologist).

Who will see my child's information?

All information from the study will be seen only by me and my research supervisors. The information from these assessments will be shared with you, as well as your child's local speech and language therapist and teacher of the hearing-impaired, **if** you give permission

What happens with my child's test results?

- Your information will be kept anonymously; this means it will not have your child's name on it. When publishing or presenting the results of the study, your child's identity will be kept anonymous.
- All information including audio and video recordings will be anonymised and kept in a locked cabinet, in a locked office at Manchester Metropolitan University (MMU) for a period of five years. This will allow for the possibility a follow up study
- Data analysis will be carried out on a password protected laptop computer on MMU premises. No identifiable personal information will be saved on the laptop.

What if I have a concern or complaint about the research study?

If you have any queries, concerns or complaints about any aspect of the study, please contact me, Suzi Willis. If you remain unhappy and wish to take the matter further, you may contact my supervisor, Juliet Goldbart. Our details are as follows:

I can be contacted at MMU by:

Telephone: 0161 247 4639

E-mail: s.willis@mmu.ac.uk

Post: Suzi Willis, Speech & Language Therapist, Faculty of Health, Psychology & Social Care, Manchester Metropolitan University, Hathersage Road, Manchester, M13 0JA

My supervisor, Juliet Goldbart can be contacted at MMU by:

Telephone: 0161 247 2578

E-mail: j.goldbart@mmu.ac.uk

Post: Professor Juliet Goldbart, Professor of Developmental Disabilities, Faculty of Health, Psychology & Social Care, Manchester Metropolitan University, Hathersage Road, Manchester, M13 0JA

If you remain unhappy and would like to discuss your concerns with someone who is independent of the project, you may also contact the Director of the Research Institute for Health and Social Change,

Carolyn Kagan. Her details are:

Telephone:0161 247-2563

E-mail: c.kagan@mmu.ac.uk

Post: Professor Carloyn Kagan, RIHSC, Faculty of Health, Psychology & Social Care, Manchester Metropolitan University, Hathersage Road, Manchester, M13 0JA

What if I still have questions about the study?

If you would like to ask any questions or get more information about the study, I would be happy to speak with you. Please contact me using the details above on this page of the information sheet.

Thank you for your time.

Suzi Willis

Please fill in your child's name and initial the appropriate box.

Please return to this slip to your child's teacher of the hearing-impaired

---

I would like _______________ to participate in the research project ☐

I would **NOT** like_____________ to participate in the research project ☐

Appendix 1D Parent Consent Form

CONSENT FORM

Title: A longitudinal study of atypical language learners with hearing impairment

Name of Researcher: Suzi Willis

	Please initial box
1. I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions	☐
2. I understand that my child's participation is voluntary and that we are free to withdraw at any time, without giving any reason and that the child's medical care or legal rights will not be affected. I understand that information provided up to the point of withdrawal may have already been used in the study on an anonymised basis	☐
3. I confirm that I consent for my child to take part in the study	☐
4. I understand that data collected during the study may be looked at by the researcher's supervisors from Manchester Metropolitan University, where it is relevant to my child taking part in this research. I give permission for these authorised individuals to have access to my child's data	☐
5. I consent for my child's anonymised data to be retained for up to 5 years, to allow for the possibility of a follow up study.	Yes/No (circle)
6. I consent for video recordings of assessments to be made of my child	Yes/No (circle)
7. I consent for my child's video recordings to be kept for up to 5 years, to allow for further analysis and for the possibility of a follow up study of participants. I am aware that the videos will then be destroyed after this time	Yes/No (circle)
8. I would like to receive information about my child arising from the study	Yes/No (circle)
9. I would like my child's speech & language therapist to	Yes/No (circle)

receive the language and memory assessment results.	
10. I would like my child's teacher of the hearing-impaired to receive the language and memory assessment results	Yes/No (circle)
11. I would like to receive a summary of the results of the study	Yes/No (circle)

____

Name of Participant (Youth)

______________________________ ____________

Signature (parent/carer) Date

______________________________ ____________

Signature (researcher) Date

Appendix 1E Parent Information and Consent Form for Informal Memory Test

<u>Invitation to Take Part in a Pilot Study</u>

24th November 2009

Pilot Project Information

I want to tell you about some research that I am asking your child to take part in. This project has been passed by an independent Research Ethics Committee and by my university's Faculty Research and Enterprise Committee.

The project that I am doing is about children who use hearing aids or cochlear implants and find it hard to learn new words.

<u>What is the project about</u>?

I want to see why some children with a hearing loss find learning and remembering new words difficult.

<u>Why have children with normal hearing been asked to take part?</u>

Typically developing children in Years 2, 3, 4 and 5 have been asked to take part in this project because I want to see how children with normal hearing name pictures and remember them.

What will happen if my child takes part in the pilot project?

I do not need any specific information about your child other than what year they are in school. Your child's name will not be put on the notes that I make when looking at the sets of pictures with your child.

I will see your child for approximately 10 minutes at school and ask him/her to name 5 everyday pictures. I will then take away the 5 pictures and see which ones your child can remember. I will do this activity with 6 different sets of pictures. When your child is finished, I will thank him/her and give them a sticker, if appropriate.

Who is in charge of the pilot project?

The study is being carried out by Suzi Willis. I am a specialist speech and language therapist and have worked with children for 18 years. I have a CRB with Oswald Road Primary School and have been coming into school for 5 years teaching sign language.

What happens with the work that my child does?

The results of the pilot project will help me make more sense of how children with and without a hearing loss name and remember pictures.

<u>What if I have questions about the pilot project?</u>

If you would like to ask any questions or get more information about the project, I would be happy to speak with you. Please contact me using the details at the bottom of this information sheet.

Please fill in your child's name and return to this slip to your child's teacher if you would NOT like your child to participate

I would <u>NOT</u> like________ to participate in the research project ☐

Class ________

Thank you for reading this!

Suzi Willis M.A., CCC-SLP Specialist Speech & Language Therapist

Senior Lecturer in Speech Pathology & Therapy

Manchester Metropolitan University

Address: Faculty of Health, Psychology & Social Care,

Manchester Metropolitan University,

Hathersage Road, Manchester, M13 0JA

telephone: 0161 247-4639 e-mail: s.willis@mmu.ac.uk

Appendix 1F NHS Ethical Approval Letter

North West 7 Research Ethics Committee - Greater Manchester Central
Room 181
Gateway House
Piccadilly South
Manchester
M60 7LP

Telephone: 0161-237-2153
Facsimile: 0161-237-2383

28 October 2009

Ms S Willis
Senior Lecturer in Speech Pathology & Therapy
Manchester Metropolitan University
Dept. of Health Professions
Elizabeth Gaskell Site
Hathersage Road
Manchester
M13 0JA

Dear Ms Willis

Study Title:	**A longitudinal study of atypical language learners with hearing-impairment and the perceived implications in educational settings**
REC reference number:	**09/H1008/109**
Protocol number:	**1**

Thank you for your letter of 2 October 2009, responding to the Committee's request for further information on the above research and submitting revised documentation.

The further information has been considered on behalf of the Committee by the Chair.

Confirmation of ethical opinion

On behalf of the Committee, I am pleased to confirm a favourable ethical opinion for the above research on the basis described in the application form, protocol and supporting documentation as revised, subject to the conditions specified below.

Ethical review of research sites

The favourable opinion applies to all NHS sites taking part in the study, subject to management permission being obtained from the NHS/HSC R&D office prior to the start of the study (see "Conditions of the favourable opinion" below).

Conditions of the favourable opinion

The favourable opinion is subject to the following conditions being met prior to the start of the study.

<u>Management permission or approval must be obtained from each host organisation prior to the start of the study at the site concerned.</u>

For NHS research sites only, management permission for research ("R&D approval") should be obtained from the relevant care organisation(s) in accordance with NHS research governance arrangements. Guidance on applying for NHS permission for research is available in the Integrated Research Application System or at http://www.rdforum.nhs.uk.

Sponsors are not required to notify the Committee of approvals from host organisations.

It is the responsibility of the sponsor to ensure that all the conditions are complied with before the start of the study or its initiation at a particular site (as applicable).

Approved documents

The final list of documents reviewed and approved by the Committee is as follows:

Document	*Version*	*Date*
Covering Letter	1	22 July 2009
REC application	2.2	10 August 2009
Investigator CV	S.Willis	
Investigator CV	J.Goldbart	
Participant Consent Form: Teacher Consent Form	1	01 July 2009
GP/Consultant Information Sheets	1	01 July 2009
Evidence of insurance or indemnity	1	30 July 2009
Letter from Sponsor	1	27 July 2009
Referees or other scientific critique report	1	17 June 2009
Parent Invitation Letter	1	30 September 2009
Younger child information sheet	1	30 September 2009
Parent information sheet	2	30 September 2009
Adolescent information sheet	2	30 September 2009
Teacher information sheet	2	30 September 2009
Response to Request for Further Information		02 October 2009
Protocol	2	30 September 2009
Parent Consent Form	2	30 September 2009
Adolescent Consent Form	2	30 September 2009

Statement of compliance

The Committee is constituted in accordance with the Governance Arrangements for Research Ethics Committees (July 2001) and complies fully with the Standard Operating Procedures for Research Ethics Committees in the UK.

After ethical review

Now that you have completed the application process please visit the National Research Ethics Service website > After Review

You are invited to give your view of the service that you have received from the National Research Ethics Service and the application procedure. If you wish to make your views known please use the feedback form available on the website.

The attached document *"After ethical review – guidance for researchers"* gives detailed guidance on reporting requirements for studies with a favourable opinion, including:

- Notifying substantial amendments
- Adding new sites and investigators
- Progress and safety reports
- Notifying the end of the study

The NRES website also provides guidance on these topics, which is updated in the light of changes in reporting requirements or procedures.

We would also like to inform you that we consult regularly with stakeholders to improve our service. If you would like to join our Reference Group please email referencegroup@nres.npsa.nhs.uk.

09/H1008/109	**Please quote this number on all correspondence**

Yours sincerely

Dr D Mandal
Chair

Email: kath.osborne@northwest.nhs.uk

Enclosures: "After ethical review – guidance for researchers"

Copy to: Professor V Edwards Jones
Acting Director of Research, Enterprise & Development
Manchester Metropolitan University
Ormond Building
Manchester
M13 6BX

Appendix 1G University Ethical Approval Form

Application Number..1007.............. **(facultycoding)**
(Sep 2007)

Date.....23.11.09...........

Manchester
Metropolitan
University

MANCHESTER METROPOLITAN UNIVERSITY
FACULTY OF HEALTH, PSYCHOLOGY AND SOCIAL CARE

APPLICATION FOR ETHICAL APPROVAL

Introduction
All university activity must be reviewed for ethical approval. In particular, all undergraduate, postgraduate and staff research work, projects and taught programmes must obtain approval from their Faculty Academic Ethics committee (or delegated Departmental Ethics Committee).

APPLICATION PROCEDURE

The form should be completed legibly (preferably typed) and, so far as possible, in a way which would enable a layperson to understand the aims and methods of the research. Every relevant section should be completed. Applicants should also include a copy of any proposed advert, information sheet, consent form and, if relevant, any questionnaire being used. The Principal Investigator should sign the application form. Supporting documents, together with one copy of the full protocol should be sent to the Administrator of the appropriate Faculty Academic Ethics Committee.

Your application will require external ethical approval by an NHS Research Ethics
Committee if your research involves staff, patients or premises of the NHS (see guidance notes)

Work with children and vulnerable adults
You will be required to have a Criminal Disclosure, if your work involves children or vulnerable adults.

The Faculty Academic Ethics Committee meets regularly and will respond as soon as possible, and where appropriate, will operate a process of expedited review. Applications that require approval by an NHS Research Ethics Committee or a Criminal Disclosure will take longer - perhaps 3 months.

1. DETAILS OF APPLICANT (S)

1.1 Principal Investigator: (Member of staff or student responsible for work)
Name, qualifications, post held, tel. no, e-mail

Suzi Willis, M.A, CCC-SLP, Senior Lecturer in Speech Pathology & Therapy
(s.willis@mmu.ac.uk; 247-4639)

1.2 Co-Workers and their role in the project: (e.g. students, external collaborators, etc) NONE

1.3 University Department/Research Institute/Other Unit:
RIHSC

2. DETAILS OF THE PROJECT

2.1 Title: A longitudinal study of atypical language learners with hearing-impairment and the perceived implications in educational settings

2.2 Description of Project: (please **outline** the background and the purpose of the research project, 250 words max.).

One to three children per 1000 births each year are diagnosed with permanent childhood hearing loss (Bamford et al., 2007). New technologies such as digital hearing aids and cochlear implants have now made it possible for many children with moderate, severe and profound hearing impairments to acquire age appropriate spoken language after an initial, expected language delay of two to four years (Geers et al., 2009; Nicholas & Geers, 2007; Yoshinaga-Itano, 2006). However, there are still significant numbers of hearing-impaired children presenting with considerable delays in all areas of language, even after several years of device use and intensive support from parents and professionals (Blamey et al., 2001; Kiese-Himmel & Reeh, 2006). The reasons for this are, as yet, unclear. A methodological difficulty with research into language outcomes in hearing-impaired children is that it does not define the type or frequency of intervention children receive. Instead, studies state the children's primary mode of communication (i.e. oral or total communication) and educational setting.

To date, there are no known studies that comprehensively investigate the language and memory abilities of children with hearing impairment over several years. Developing a clearer definition, description and profile of the kinds of language and memory difficulties children with hearing-impairment present with, will help professionals to differentiate between different disorders of communication, and thus allow for more targeted intervention.

The primary aim of this project will be to establish more effective ways of describing language difficulties in hearing-impaired children. The study will evaluate approximately 6 to 8 children's receptive and expressive language, phonological awareness, narrative skills and memory abilities annually for a period of three years.

2.3 Are you going to use a questionnaire? NO
(Please attach a copy)

2.4 Start Date / Duration of project: 5 years

2.5 Location of where the project and data collection will take place: [redacted]

2.6 Nature/Source of funding: PhD is funded by Professional Registration Division

2.7 Are there any regulatory requirements? YES/NO/N/A
If yes, please give details, e.g., from relevant professional bodies

3. DETAILS OF PARTICIPANTS

3.1 How many? Approximately 8

3.2 Age: 6-16

3.3 Sex: male or female

3.4 How will they be recruited? Letter of Invitation and Participant Information Sheet

3.5 Status of participants: (e.g. students, public, colleagues, children, hospital patients, prisoners, including young offenders, participants with mental illness or learning difficulties.) Children

3.6 Inclusion and exclusion from the project: (indicate the criteria to be applied).

The study's primary focus is on hearing-impaired children who are not developing age-appropriate spoken language, despite intensive support. The children/adolescents use spoken language to communicate their needs, but may have begun to use sign language in order to support their spoken language learning. Variables such as sign language use as primary mode of communication, English as an additional language or identifiable learning difficulties may influence the outcomes of the study, so therefore the following inclusion and exclusion criteria need to be specified.

Inclusion Criteria	Exclusion Criteria
- Mild to Severe hearing loss - Fitted with hearing device by age 2½ years - Speech is primary mode of communication - Home language is English - Live in North West England - Minimum age 6 - Maximum age 16 -Typically developing (with the exception of speech and language) -Educational Psychologist Involvement	-Identifiable learning difficulties -Sign language as primary mode of communication -Language other than English

3.7 Payment to volunteers: (indicate any sums to be paid to volunteers). NONE

3.8 Study information:

Have you provided a study information sheet for the participants? YES
Please attach a copy of the information sheet, where appropriate

3.9 Consent:

(A written consent form for the study participants MUST be provided in all cases, unless the research is a questionnaire.)

Have you produced a written consent form for the participants to sign for your records? YES

Please attach as appropriate.

4. RISKS AND HAZARDS

Please respond to the following questions if applicable

4.1 Are there any risks to the researcher and/or participants?

(Give details of the procedures and processes to be undertaken, e.g., if the researcher is a lone-worker.)

The researcher will be assessing the children in the local school

4.2 State precautions to minimise the risks and possible adverse events:

As a speech and language therapist with 15 years experience, I am confident that I conduct sessions in a relaxed and playful manner. Thus, minimizing any upset.

4.3 What discomfort (physical or psychological) danger or interference with normal activities might be suffered by the researcher and/or participant(s)? State precautions which will be taken to minimise them: Children will be seen at school in order to minimize disruption. If the child does not want to participate in an assessment, then the session will be stopped. If the child would like to leave, they may or stay and play a game or look at a magazine.

5. PLEASE DESCRIBE ANY ETHICAL ISSUES RAISED AND HOW YOU INTEND TO ADDRESS THESE:

Teachers of the hearing-impaired will be the gate keepers and indentify children with hearing-impaiment who meet the inclusion criteria. The teachers will give the Letter of Invitation and Participant Information Sheets for the parent to read.

The Informed consent process will be initiated by the provision of a Letter of Invitation, Participant Information Sheet and a Consent Form. Parents/guardians of potential participants will be given at least 24 hours to read the written information sheet prior to meeting the researcher. The parents/guardian of potential participants will have the opportunity to discuss the project in person with the researcher prior to consent being given. Two copies of the consent form will be completed and signed by the parent/guardian. The researcher will retain one copy of the consent form and the participants will also retain one copy. The participants may with draw their consent at any point, without giving a reason.

6. SAFEGUARDS /PROCEDURAL COMPLIANCE

6.1 Confidentiality:

(a) Indicate what steps will be taken to safeguard the confidentiality of participant records. If the data is to be computerised, it will be necessary to ensure compliance with the requirements of the Data Protection Act.

Participants' audio recordings and video recordings of assessments, consent forms, the assessment results, and audio-recordings from teacher interviews will be anonymised and kept in a locked cabinet, in a locked office on MMU premises. Data analysis will be carried out on a password protected laptop computer on MMU premises. No identifiable personal information will be saved on the laptop. Participants' anonymity will be maintained when publishing or presenting the results of the study.

(b) If you are intending to make any kind of audio or visual recordings of the participants, please answer the following questions:

a. How long will the recordings be retained and how will they be stored? Assessment results and recordings will be kept for 5 years, to allow for the possibility of a follow up study.

b. How will they be destroyed at the end of the project? Via MMU Procedure

c. What further use, if any, do you intend to make of the recordings? To allow for the possibility of a follow up study by comparing and contrasting communication style and compensatory strategies.

6.2 Human Tissue Act: N/A

The Human Tissue Act came into force in November 2004, and requires appropriate consent for, and regulates the removal, storage and use of all human tissue.

a. Does your project involve taking tissue samples, e.g., blood, urine, hair, etc., from human subjects? N/A

b. Will this be discarded when the project is terminated? N/A

If NO – Explain how the samples will be placed into a tissue bank under the Human Tissue Act regulations:

6.3 Insurance:

The University holds insurance policies that will cover claims for negligence arising from the conduct of the University's normal business, which includes research carried out by staff and by undergraduate and postgraduate students as part of their courses. This does **not** extend to clinical negligence. There are no arrangements to provide indemnity and/or compensation in the event of claims for non-negligent harm.

Will the proposed project result in you undertaking any activity that would not be considered as normal University business? NO

6.4 Notification of Adverse Events (e.g., negative reaction, counsellor, etc):
(Indicate precautions taken to avoid adverse reactions.)

Please state the processes/procedures in place to respond to possible adverse reactions. N/A

In the case of clinical research, you will need to abide by specific guidance. This may include notification to GP and ethics committee. **Please seek guidance for up to date advice**, e.g., see the NRES website at http://www.nres.npsa.nhs.uk/

SIGNATURE OF PRINCIPAL INVESTIGATOR DATE:

.... 23/11/10 ....

SIGNATURE OF FACULTY ACADEMIC ETHICS COMMITTEE CHAIRPERSON: DATE:

.... 26/11/10 ....

Appendix 1H Amendment to NHS Ethical Approval

NHS
Health Research Authority

NRES Committee North West - Greater Manchester Central
3rd Floor
Barlow House
4 Minshull Street
Manchester
M1 3DZ

Tel: 0161 625 7825
Fax: 0161 625 7299

16 February 2012

Ms Suzi Willis
Senior Lecturer in Speech Pathology & Therapy
Manchester Metropolitan University
Dept. of Health Professions
Elizabeth Gaskell Site,
Hathersage Rd., Manchester
M13 0JA

Dear Ms Willis

Study title:	**A longitudinal study of atypical language learners with hearing-impairment and the perceived implications in educational settings**
REC reference:	**09/H1008/109**
Protocol number:	**REC09/09**
Amendment number:	**1**
Amendment date:	**05 January 2012**

The above amendment was reviewed at the meeting of the Sub-Committee held on 10 February 2012.

The amendment sought approval to provide therapeutic input and advice to three hearing-impaired children, on three occasions over a 9-12 month period. The sessions would be video-taped and copies would be provided to parents and specialist teachers. Interviewing teachers of the hearing-impaired will no longer be undertaken.

Ethical opinion

The members of the Committee taking part in the review gave a favourable ethical opinion of the amendment on the basis described in the notice of amendment form and supporting documentation.

Approved documents

The documents reviewed and approved at the meeting were:

Document	Version	Date
Protocol/Proposal	2	01 January 2009
Participant Information Sheet	2	05 January 2012
Participant Information Sheet	3	05 January 2012
Notice of Substantial Amendment (non-CTIMPs)	1	05 January 2012
Covering Letter		10 January 2012

Appendix 2 Participant Audiological Information

Note: Hearing levels are in dB HL

Child A: Sloping hearing loss with mild to moderate hearing loss in the low frequencies and a severe hearing loss in the high frequencies; HA fitted at 10 months.

	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Right Ear (unaided)	30	35	60	75	80
Left Ear (unaided)	50	55	85	95	90
Aided	10	20	15	20	25

Child B: Bilateral severe to profound hearing loss; HA fitted at 12 months; Usable residual hearing in the low to mid frequencies providing pattern perception and first formant vowel information); CI fitted age 2;6

	250 Hz	500 Hz	1000Hz	2000 Hz	4000 Hz
Right Ear CI	30	35	30	30	35

Child C: Progressive bilateral severe hearing loss; HA fitted at age 12 months; Usable residual hearing in the low to mid/high frequencies, out to 2000 Hz providing pattern perception and vowel information; CI fitted age 3;2.

	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Left Ear CI	30	20	20	20	25

Child D: Bilateral severe to profound hearing loss, with a mild to moderate loss in the left ear in the high frequencies. Fitted with HA at age 1;10

	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Right Ear (unaided)	90	95	90	90	90
Left Ear (unaided)	70	70	70	40	35
Aided	40	30	35	20	10

Child E: Bilateral severe to profound progressive loss. Able to detect speech sounds across the speech frequencies when wearing HA. Fitted with HA at age 1;6

	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Right Ear (unaided)	65	85	100	95	80
Left Ear (unaided)	75	80	95	95	75
Aided	30	40	45	40	30

Child F: Bilateral severe hearing Loss; Diagnosed at 1;6. Fitted with CI at age 2;6

	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Right Ear CI	20	20	20	15	15

Appendix 3 EVT and BPVS Tests ANOVA and t-tests

Tests of Within-Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
year	Sphericity Assumed	1.722	2	.861	.039	.962
	Greenhouse-Geisser	1.722	1.323	1.302	.039	.906
	Huynh-Feldt	1.722	1.615	1.067	.039	.936
	Lower-bound	1.722	1.000	1.722	.039	.851
Error(year)	Sphericity Assumed	220.278	10	22.028		
	Greenhouse-Geisser	220.278	6.615	33.302		
	Huynh-Feldt	220.278	8.074	27.284		
	Lower-bound	220.278	5.000	44.056		
tests	Sphericity Assumed	950.694	1	950.694	58.584	.001
	Greenhouse-Geisser	950.694	1.000	950.694	58.584	.001
	Huynh-Feldt	950.694	1.000	950.694	58.584	.001
	Lower-bound	950.694	1.000	950.694	58.584	.001
Error(tests)	Sphericity Assumed	81.139	5	16.228		
	Greenhouse-Geisser	81.139	5.000	16.228		
	Huynh-Feldt	81.139	5.000	16.228		
	Lower-bound	81.139	5.000	16.228		
year * tests	Sphericity Assumed	102.389	2	51.194	6.712	.014
	Greenhouse-Geisser	102.389	1.325	77.297	6.712	.032
	Huynh-Feldt	102.389	1.618	63.272	6.712	.023
	Lower-bound	102.389	1.000	102.389	6.712	.049
Error(year*tests)	Sphericity Assumed	76.278	10	7.628		
	Greenhouse-Geisser	76.278	6.623	11.517		
	Huynh-Feldt	76.278	8.091	9.427		
	Lower-bound	76.278	5.000	15.256		

Pairwise Comparisons

Measure:MEASURE_1

(I) Years	(J) Years	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	.083	1.044	1.000	-3.607	3.774
	3	.500	2.320	1.000	-7.700	8.700
2	1	-.083	1.044	1.000	-3.774	3.607
	3	.417	2.131	1.000	-7.114	7.947
3	1	-.500	2.320	1.000	-8.700	7.700
	2	-.417	2.131	1.000	-7.947	7.114

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Paired Samples Test

		Paired Differences Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	BPVS Year1 - EVT Year1	-7.33333	4.67618	1.90904	-12.24068	-2.42598	-3.841	5	.012
Pair 2	BPVS Year2 - EVT Year2	-8.50000	4.84768	1.97906	-13.58733	-3.41267	-4.295	5	.008
Pair 3	BPVS Year3 - EVT Year3	-15.00000	4.19524	1.71270	-19.40263	-10.59737	-8.758	5	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	EVT Year1 - EVT Year2	-.50000	1.87083	.76376	-2.46331	1.46331	-.655	5	.542
Pair 2	EVT Year2 - EVT Year 3	-2.83333	5.11534	2.08833	-8.20155	2.53488	-1.357	5	.233
Pair 3	EVT Year1 - EVT Year 3	-3.33333	5.98888	2.44495	-9.61828	2.95161	-1.363	5	.231

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	BPVS Year1 - BPVS Year2	.66667	3.93277	1.60555	-3.46052	4.79385	.415	5	.695
Pair 2	BPVS Year2 - BPVS Year3	3.66667	7.28469	2.97396	-3.97814	11.31148	1.233	5	.272
Pair 3	BPVS Year1 - BPVS Year3	4.33333	6.62319	2.70391	-2.61728	11.28395	1.603	5	.170

Pairwise Comparisons

Measure:MEASURE_1

(I) Tests	(J) Tests	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	-10.278*	1.343	.001	-13.730	-6.826
2	1	10.278*	1.343	.001	6.826	13.730

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Bonferroni.

Years * Tests

Measure:MEASURE_1

Years	Tests	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
1	1	67.500	1.118	64.626	70.374
	2	74.833	1.778	70.263	79.404
2	1	66.833	1.222	63.691	69.976
	2	75.333	1.647	71.101	79.566
3	1	63.167	2.725	56.161	70.173
	2	78.167	3.270	69.760	86.573

Test 1 = BPVS Test 2= EVT

Appendix 4 CELF-4UK Receptive Tests ANOVA

No Significant Difference

Tests of Within-Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Years	Sphericity Assumed	5.267	2	2.633	.798	.483
	Greenhouse-Geisser	5.267	1.133	4.647	.798	.433
	Huynh-Feldt	5.267	1.279	4.118	.798	.444
	Lower-bound	5.267	1.000	5.267	.798	.422
Error(Years)	Sphericity Assumed	26.400	8	3.300		
	Greenhouse-Geisser	26.400	4.533	5.823		
	Huynh-Feldt	26.400	5.116	5.160		
	Lower-bound	26.400	4.000	6.600		
Tests	Sphericity Assumed	20.833	1	20.833	.951	.385
	Greenhouse-Geisser	20.833	1.000	20.833	.951	.385
	Huynh-Feldt	20.833	1.000	20.833	.951	.385
	Lower-bound	20.833	1.000	20.833	.951	.385
Error(Tests)	Sphericity Assumed	87.667	4	21.917		
	Greenhouse-Geisser	87.667	4.000	21.917		
	Huynh-Feldt	87.667	4.000	21.917		
	Lower-bound	87.667	4.000	21.917		
Years * Tests	Sphericity Assumed	4.867	2	2.433	1.377	.306
	Greenhouse-Geisser	4.867	1.794	2.713	1.377	.307
	Huynh-Feldt	4.867	2.000	2.433	1.377	.306
	Lower-bound	4.867	1.000	4.867	1.377	.306
Error(Years*Tests)	Sphericity Assumed	14.133	8	1.767		
	Greenhouse-Geisser	14.133	7.176	1.970		
	Huynh-Feldt	14.133	8.000	1.767		
	Lower-bound	14.133	4.000	3.533		

Receptive Tests = Word Classes (Receptive) and Understanding Paragraphs

Year Differences

Pairwise Comparisons

Measure:MEASURE_1

(I) Years	(J) Years	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-1.000	.354	.142	-2.400	.400
	3	-.700	1.056	1.000	-4.882	3.482
2	1	1.000	.354	.142	-.400	2.400
	3	.300	.860	1.000	-3.107	3.707
3	1	.700	1.056	1.000	-3.482	4.882
	2	-.300	.860	1.000	-3.707	3.107

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Estimates

Measure:MEASURE_1

Years	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	5.800	.339	4.858	6.742
2	6.800	.436	5.590	8.010
3	6.500	1.225	3.100	9.900

Test Differences

Pairwise Comparisons

Measure:MEASURE_1

(I) Tests	(J) Tests	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-1.667	1.709	.385	-6.413	3.080
2	1	1.667	1.709	.385	-3.080	6.413

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Appendix 5 CELF-4UK Expressive Tests ANOVA

Tests of Within-Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Years	Sphericity Assumed	5.200	2	2.600	1.093	.380
	Greenhouse-Geisser	5.200	1.522	3.418	1.093	.372
	Huynh-Feldt	5.200	2.000	2.600	1.093	.380
	Lower-bound	5.200	1.000	5.200	1.093	.355
Error(Years)	Sphericity Assumed	19.022	8	2.378		
	Greenhouse-Geisser	19.022	6.086	3.125		
	Huynh-Feldt	19.022	8.000	2.378		
	Lower-bound	19.022	4.000	4.756		
Tests	Sphericity Assumed	250.533	2	125.267	142.709	.000
	Greenhouse-Geisser	250.533	1.175	213.200	142.709	.000
	Huynh-Feldt	250.533	1.372	182.614	142.709	.000
	Lower-bound	250.533	1.000	250.533	142.709	.000
Error(Tests)	Sphericity Assumed	7.022	8	.878		
	Greenhouse-Geisser	7.022	4.700	1.494		
	Huynh-Feldt	7.022	5.488	1.280		
	Lower-bound	7.022	4.000	1.756		
Years * Tests	Sphericity Assumed	8.667	4	2.167	1.114	.384
	Greenhouse-Geisser	8.667	1.662	5.216	1.114	.369
	Huynh-Feldt	8.667	2.698	3.212	1.114	.380
	Lower-bound	8.667	1.000	8.667	1.114	.351
Error(Years*Tests)	Sphericity Assumed	31.111	16	1.944		
	Greenhouse-Geisser	31.111	6.647	4.681		
	Huynh-Feldt	31.111	10.792	2.883		
	Lower-bound	31.111	4.000	7.778		

Tests = Word Classes Expressive, Recalling Sentences, Formulating Sentences

Year Comparisons for the Expressive Assessments

Pairwise Comparisons

Measure: MEASURE_1

(I) Year	(J) Year	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-.600	.386	.585	-2.128	.928
	3	-.800	.672	.898	-3.460	1.860
2	1	.600	.386	.585	-.928	2.128
	3	-.200	.593	1.000	-2.547	2.147
3	1	.800	.672	.898	-1.860	3.460
	2	.200	.593	1.000	-2.147	2.547

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Tests: Word Classes Expressive (1), Recalling Sentences (2), Formulating Sentences (3)

Pairwise Comparisons

Measure:MEASURE_1

(I) Tests	(J) Tests	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	4.867*	.455	.001	3.066	6.667
	3	5.133*	.327	.000	3.840	6.427
2	1	-4.867*	.455	.001	-6.667	-3.066
	3	.267	.194	.726	-.503	1.037
3	1	-5.133*	.327	.000	-6.427	-3.840
	2	-.267	.194	.726	-1.037	.503

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Bonferroni.

Estimates

Measure:MEASURE_1

Tests	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	6.333	.258	5.616	7.050
2	1.467	.389	.387	2.546
3	1.200	.200	.645	1.755

Appendix 6 CELF-4UK Word Classes Receptive versus Expressive Tests ANOVA

No Significant Difference

Tests of Within-Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
year	Sphericity Assumed	11.667	2	5.833	.628	.558
	Greenhouse-Geisser	11.667	1.580	7.382	.628	.528
	Huynh-Feldt	11.667	2.000	5.833	.628	.558
	Lower-bound	11.667	1.000	11.667	.628	.473
Error(year)	Sphericity Assumed	74.333	8	9.292		
	Greenhouse-Geisser	74.333	6.322	11.759		
	Huynh-Feldt	74.333	8.000	9.292		
	Lower-bound	74.333	4.000	18.583		
tests	Sphericity Assumed	4.800	1	4.800	4.235	.109
	Greenhouse-Geisser	4.800	1.000	4.800	4.235	.109
	Huynh-Feldt	4.800	1.000	4.800	4.235	.109
	Lower-bound	4.800	1.000	4.800	4.235	.109
Error(tests)	Sphericity Assumed	4.533	4	1.133		
	Greenhouse-Geisser	4.533	4.000	1.133		
	Huynh-Feldt	4.533	4.000	1.133		
	Lower-bound	4.533	4.000	1.133		
year * tests	Sphericity Assumed	3.800	2	1.900	2.214	.172
	Greenhouse-Geisser	3.800	1.345	2.825	2.214	.197
	Huynh-Feldt	3.800	1.780	2.135	2.214	.180
	Lower-bound	3.800	1.000	3.800	2.214	.211
Error(year*tests)	Sphericity Assumed	6.867	8	.858		
	Greenhouse-Geisser	6.867	5.381	1.276		
	Huynh-Feldt	6.867	7.121	.964		
	Lower-bound	6.867	4.000	1.717		

Pairwise Comparisons

Measure:MEASURE_1

(I) Years	(J) Years	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-1.000	.975	1.000	-4.860	2.860
	3	-1.500	1.605	1.000	-7.856	4.856
2	1	1.000	.975	1.000	-2.860	4.860
	3	-.500	1.432	1.000	-6.171	5.171
3	1	1.500	1.605	1.000	-4.856	7.856
	2	.500	1.432	1.000	-5.171	6.171

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Appendix 7 Verbal Short-Term Memory Tests ANOVA

Tests of Within-Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Years	Sphericity Assumed	240.444	2	120.222	.947	.420
	Greenhouse-Geisser	240.444	1.532	156.934	.947	.404
	Huynh-Feldt	240.444	2.000	120.222	.947	.420
	Lower-bound	240.444	1.000	240.444	.947	.375
Error(Years)	Sphericity Assumed	1270.000	10	127.000		
	Greenhouse-Geisser	1270.000	7.661	165.782		
	Huynh-Feldt	1270.000	10.000	127.000		
	Lower-bound	1270.000	5.000	254.000		
Tests	Sphericity Assumed	10650.111	2	5325.056	23.049	.000
	Greenhouse-Geisser	10650.111	1.535	6936.822	23.049	.001
	Huynh-Feldt	10650.111	2.000	5325.056	23.049	.000
	Lower-bound	10650.111	1.000	10650.111	23.049	.005
Error(Tests)	Sphericity Assumed	2310.333	10	231.033		
	Greenhouse-Geisser	2310.333	7.677	300.962		
	Huynh-Feldt	2310.333	10.000	231.033		
	Lower-bound	2310.333	5.000	462.067		
Years * Tests	Sphericity Assumed	360.111	4	90.028	1.734	.182
	Greenhouse-Geisser	360.111	2.018	178.412	1.734	.225
	Huynh-Feldt	360.111	3.391	106.196	1.734	.194
	Lower-bound	360.111	1.000	360.111	1.734	.245
Error(Years*Tests)	Sphericity Assumed	1038.111	20	51.906		
	Greenhouse-Geisser	1038.111	10.092	102.863		
	Huynh-Feldt	1038.111	16.955	61.227		
	Lower-bound	1038.111	5.000	207.622		

Tests = Non-word Recall, Word Recall and Digit Recall

Year Differences

Pairwise Comparisons

Measure:MEASURE_1

(I) Years	(J) Years	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-1.889	4.388	1.000	-17.397	13.620
	3	3.222	2.542	.783	-5.763	12.208
2	1	1.889	4.388	1.000	-13.620	17.397
	3	5.111	4.076	.796	-9.293	19.516
3	1	-3.222	2.542	.783	-12.208	5.763
	2	-5.111	4.076	.796	-19.516	9.293

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Test Differences

Pairwise Comparisons

Measure:MEASURE_1

(I) Tests	(J) Tests	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	31.611*	3.957	.001	17.628	45.594
	3	27.556*	6.269	.021	5.400	49.711
2	1	-31.611*	3.957	.001	-45.594	-17.628
	3	-4.056	4.696	1.000	-20.653	12.542
3	1	-27.556*	6.269	.021	-49.711	-5.400
	2	4.056	4.696	1.000	-12.542	20.653

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Bonferroni.

Appendix 8 Verbal Working Memory Tests ANOVA

No Significant Difference

Tests of Within-Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
year	Sphericity Assumed	136.500	2	68.250	.527	.606
	Greenhouse-Geisser	136.500	1.576	86.608	.527	.569
	Huynh-Feldt	136.500	2.000	68.250	.527	.606
	Lower-bound	136.500	1.000	136.500	.527	.500
Error(year)	Sphericity Assumed	1294.167	10	129.417		
	Greenhouse-Geisser	1294.167	7.880	164.227		
	Huynh-Feldt	1294.167	10.000	129.417		
	Lower-bound	1294.167	5.000	258.833		
tests	Sphericity Assumed	552.250	1	552.250	1.186	.326
	Greenhouse-Geisser	552.250	1.000	552.250	1.186	.326
	Huynh-Feldt	552.250	1.000	552.250	1.186	.326
	Lower-bound	552.250	1.000	552.250	1.186	.326
Error(tests)	Sphericity Assumed	2328.917	5	465.783		
	Greenhouse-Geisser	2328.917	5.000	465.783		
	Huynh-Feldt	2328.917	5.000	465.783		
	Lower-bound	2328.917	5.000	465.783		
year * tests	Sphericity Assumed	72.167	2	36.083	.502	.620
	Greenhouse-Geisser	72.167	1.766	40.876	.502	.600
	Huynh-Feldt	72.167	2.000	36.083	.502	.620
	Lower-bound	72.167	1.000	72.167	.502	.510
Error(year*tests)	Sphericity Assumed	719.167	10	71.917		
	Greenhouse-Geisser	719.167	8.828	81.468		
	Huynh-Feldt	719.167	10.000	71.917		
	Lower-bound	719.167	5.000	143.833		

Tests = Backward Digit Recall and Listening Recall

Year Differences

Pairwise Comparisons

Measure:MEASURE_1

(I) Years	(J) Years	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	-2.000	4.911	1.000	-19.356	15.356
	3	-4.750	5.452	1.000	-24.020	14.520
2	1	2.000	4.911	1.000	-15.356	19.356
	3	-2.750	3.296	1.000	-14.398	8.898
3	1	4.750	5.452	1.000	-14.520	24.020
	2	2.750	3.296	1.000	-8.898	14.398

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Test Differences

Pairwise Comparisons

Measure:MEASURE_1

(I) Tests	(J) Tests	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-7.833	7.194	.326	-26.326	10.659
2	1	7.833	7.194	.326	-10.659	26.326

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Appendix 9 Visual Short-Term Memory and Working Memory Tests ANOVA

Tests of Within-Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Years	Sphericity Assumed	590.217	2	295.108	2.918	.112
	Greenhouse-Geisser	590.217	1.198	492.727	2.918	.151
	Huynh-Feldt	590.217	1.424	414.578	2.918	.139
	Lower-bound	590.217	1.000	590.217	2.918	.163
Error(Years)	Sphericity Assumed	808.980	8	101.123		
	Greenhouse-Geisser	808.980	4.791	168.839		
	Huynh-Feldt	808.980	5.695	142.060		
	Lower-bound	808.980	4.000	202.245		
Tests	Sphericity Assumed	1695.008	1	1695.008	17.769	.014
	Greenhouse-Geisser	1695.008	1.000	1695.008	17.769	.014
	Huynh-Feldt	1695.008	1.000	1695.008	17.769	.014
	Lower-bound	1695.008	1.000	1695.008	17.769	.014
Error(Tests)	Sphericity Assumed	381.573	4	95.393		
	Greenhouse-Geisser	381.573	4.000	95.393		
	Huynh-Feldt	381.573	4.000	95.393		
	Lower-bound	381.573	4.000	95.393		
Years * Tests	Sphericity Assumed	10.017	2	5.008	.051	.950
	Greenhouse-Geisser	10.017	1.819	5.507	.051	.939
	Huynh-Feldt	10.017	2.000	5.008	.051	.950
	Lower-bound	10.017	1.000	10.017	.051	.832
Error(Years*Tests)	Sphericity Assumed	780.047	8	97.506		
	Greenhouse-Geisser	780.047	7.275	107.216		
	Huynh-Feldt	780.047	8.000	97.506		
	Lower-bound	780.047	4.000	195.012		

Tests = Odd One Out and Block Recall

Year Differences

Pairwise Comparisons

Measure:MEASURE_1

(I) Years	(J) Years	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-8.600	4.844	.451	-27.784	10.584
	3	-10.050	5.715	.460	-32.687	12.587
2	1	8.600	4.844	.451	-10.584	27.784
	3	-1.450	2.133	1.000	-9.899	6.999
3	1	10.050	5.715	.460	-12.587	32.687
	2	1.450	2.133	1.000	-6.999	9.899

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Test Differences

Pairwise Comparisons

Measure:MEASURE_1

(I) Tests	(J) Tests	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	15.033*	3.566	.014	5.131	24.935
2	1	-15.033*	3.566	.014	-24.935	-5.131

Based on estimated marginal means

*. The mean difference is significant at the .05 level.
a. Adjustment for multiple comparisons: Bonferroni.

Appendix 10 School Data

Table A Pearson Product Moment Correlation Coefficient for Each Year Group

Correlations

year					Verbal Raw Score	Picture Raw Score
2	Verbal Raw Score	Pearson Correlation			1	.228
		Sig. (2-tailed)				.526
		N			10	10
		Bootstrap[c]	Bias		0	-.014
			Std. Error		0	.335
			BCa 95% Confidence Interval	Lower	.	-.393
				Upper	.	.808
	Picture Raw Score	Pearson Correlation			.228	1
		Sig. (2-tailed)			.526	
		N			10	10
		Bootstrap[c]	Bias		-.014	0
			Std. Error		.335	0
			BCa 95% Confidence Interval	Lower	-.393	.
				Upper	.808	.
3	Verbal Raw Score	Pearson Correlation			1	.795**
		Sig. (2-tailed)				.006
		N			10	10
		Bootstrap[c]	Bias		0	-.004
			Std. Error		0	.125
			BCa 95% Confidence Interval	Lower	.	.424
				Upper	.	.952
	Picture Raw Score	Pearson Correlation			.795**	1
		Sig. (2-tailed)			.006	
		N			10	10
		Bootstrap[c]	Bias		-.004	0
			Std. Error		.125	0
			BCa 95% Confidence Interval	Lower	.424	.
				Upper	.952	.
4	Verbal Raw Score	Pearson Correlation			1	.360
		Sig. (2-tailed)				.306
		N			10	10
		Bootstrap[c]	Bias		0	.047
			Std. Error		0	.237
			BCa 95% Confidence Interval	Lower	.	-.057
				Upper	.	.965
	Picture Raw Score	Pearson Correlation			.360	1
		Sig. (2-tailed)			.306	
		N			10	10
		Bootstrap[c]	Bias		.047	0
			Std. Error		.237	0
			BCa 95% Confidence Interval	Lower	-.057	.
				Upper	.965	.
5	Verbal Raw Score	Pearson Correlation			1	.170
		Sig. (2-tailed)				.639
		N			10	10
		Bootstrap[c]	Bias		0	.031
			Std. Error		0	.303
			BCa 95% Confidence Interval	Lower	.	-.512
				Upper	.	.932
	Picture Raw Score	Pearson Correlation			.170	1
		Sig. (2-tailed)			.639	
		N			10	10
		Bootstrap[c]	Bias		.031	0
			Std. Error		.303	0
			BCa 95% Confidence Interval	Lower	-.512	.
				Upper	.932	.

**. Correlation is significant at the 0.01 level (2-tailed).

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

^ Year 2 = children aged 7   Year 3 = children aged 8

Year 4 = children aged 9   Year 5 = children aged 10

Table B Pearson Product Moment Correlation Coefficient for the Group

Correlations

		Verbal Raw Score	Picture Raw Score	year	Gender of Child
Verbal Raw Score	Pearson Correlation	1	.732**	.640**	-.076
	Sig. (2-tailed)		.000	.000	.642
	N	40	40	40	40
Picture Raw Score	Pearson Correlation	.732**	1	.732**	.075
	Sig. (2-tailed)	.000		.000	.647
	N	40	40	40	40
year	Pearson Correlation	.640**	.732**	1	.022
	Sig. (2-tailed)	.000	.000		.893
	N	40	40	40	40
Gender of Child	Pearson Correlation	-.076	.075	.022	1
	Sig. (2-tailed)	.642	.647	.893	
	N	40	40	40	40

**. Correlation is significant at the 0.01 level (2-tailed).

Table C Informal Memory Test t- test for Verbal and Visual Task

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Verbal Raw Score - Picture Raw Score	.375	2.599	.411	-.456	1.206	.913	39	.367

Table D Descriptive Statistics for Verbal and Visual Tasks

	Mean	N	Std. Deviation	Std. Error Mean
Verbal Raw Score	**20.675**	**40**	**3.675**	**.581**
Picture Raw Score	**20.30**	**40**	**3.391**	**.536**

Table E Descriptive Statistics for Verbal and Visual tasks in relation to Gender

Group Statistics

	Gender of Child	N	Mean	Std. Deviation	Std. Error Mean
Verbal Raw Score	Boys	20	20.95	3.859	.863
	Girls	20	20.40	3.560	.796
Picture Raw Score	Boys	20	20.05	3.762	.841
	Girls	20	20.55	3.052	.682

Table F Differences between Year Groups/Ages ^

Multiple Comparisons

MEASURE_1

Bonferroni

(I) year	(J) year	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
2	3	-3.95*	.936	.001	-6.58	-1.32
	4	-6.55*	.936	.000	-9.18	-3.92
	5	-6.25*	.936	.000	-8.88	-3.62
3	2	3.95*	.936	.001	1.32	6.58
	4	-2.60	.936	.055	-5.23	.03
	5	-2.30	.936	.118	-4.93	.33
4	2	6.55*	.936	.000	3.92	9.18
	3	2.60	.936	.055	-.03	5.23
	5	.30	.936	1.000	-2.33	2.93
5	2	6.25*	.936	.000	3.62	8.88
	3	2.30	.936	.118	-.33	4.93
	4	-.30	.936	1.000	-2.93	2.33

Based on observed means.

The error term is Mean Square(Error) = 4.381.

*. The mean difference is significant at the .05 level.

^ Year 2 = children aged 7

Year 3 = children aged 8

Year 4 = children aged 9

Year 5 = children aged 10

Appendix 11 Informal Memory Test Words and Pictures

Verbal Task (Presented first)

List 1: Shirt 4, Socks 1, Coat 5, Shoes, 2, Wellies/Boots 3

List 2: Head 5, Thumb 2, Ear 3, Eye 1, Foot 4

List 3: Skates 1, Car 3, Bike 2, Plane, 5, Lorry 4

List 4: Fish1, Cat 3, Cow 5, Dog 4, Mouse 2

List 5: Chair 2, House 5, Bed 4, Sofa/Settee 3, Scissors 1

Visual Task (Presented second)

List 1: Socks 1, Shirt 4, Shoes 2, Wellies/Boots 3, Coat 5

List 2: Ear 3, Head 5, Eye 1, Foot 4, Thumb 2

List 3: Plane 5, Skates 1, Lorry 4, Car 3, Bike 2

List 4: Mouse 2, Fish 1, Dog 4, Cow 5, Cat 3

List 5: Sofa/Sette3, Chair 2, Scissors 1, House 5, Bed 4

<u>Informal Memory Test Pictures</u>

List 1:





List 2:





List 3:

List 4:

List 5:

Appendix 12 Assessment Administration

Child:		CA:	CA:	CA:
Assessments:	Order	Date	Date	Date
EVT-2 (E)	1*			
BPVS (R)	1			
Informal Memory Test	1*			
Word Recall Digit Recall Non-Word Recall	2 2 2			
Listening Recall Backward Digit	2 2			
Block Recall	2			
Odd One Out (AWMA)	2			
Recalling Sentences	3*			
Formulated Sentences	3*			
Word (8-16) Classes (Receptive)	3			
Word (8-16) Classes (Expressive)	3			
Under. Spoken Paragraphs	3			

*Video recorded

Appendix 13 Monitoring Protocol for Babies and Children

Stage B6

Communication
Development of communicative behaviour – English: Stage B6

Stage B6 – English	Possibly	Definitely	What my child does and what it tells me; how I know my child can do this
Foundations of communication English			
Waits for speaker to finish before taking their turn			
Points to desired objects to direct attention and/ or to find out about things in distance – over 3m O			
Pays attention to what people have to say for longer periods of time			
Sometimes copies a new word or features of it, (eg intonation, rhythmic pattern, and/or some of the sounds) immediately after it has been used, eg amini for 'in a minute', odier for 'oh dear' A			
Babbles freely when alone or playing			
Receptive language English			
Shows understanding of at least 15 words: eg – looks at named person – picks up toys when asked – searches for an object in its usual place etc			
Shows understanding of: – simple questions, eg where is the ball? – simple commands, eg bring me the ball when accompanied by gesture			

Communication
Development of communicative behaviour – English: Stage B6

Stage B6 – English (continued)	Possibly	Definitely	What my child does and what it tells me; how I know my child can do this
Expressive language English			
Will vocalise freely when alone or playing, sometimes with recognisable words in the vocalisation			
Uses approximately five words to express different meanings: – refers to familiar people – refers to objects – requests objects – greets – plays communicative games – protests – comments on absence or disappearance of things/people – shows things – requests 'more'/'again'			
Asks for favourite games, eg peek-a-boo by saying 'boo' or hiding face			

Stage B7

Stage B7 – English	Possibly	Definitely	What my child does and what it tells me; how I know my child can do this
Foundations of communication English			
Tugs adult or pulls their hand to indicate what they want or mean			
Is highly imitative of adult and others' – actions – gestures – vocalisations A/O			
Receptive language English			
Understands more new words each week			
Understands familiar words in new contexts each week			
Selects familiar objects, eg will go and find objects when asked or identifies objects in a group			
Follows simple instructions, particularly if accompanied by gestures, eg pointing to places, things or people A			
Identifies body parts on self (hair, eyes, ears, nose)			
Expressive language English			
Uses at least 10 words consistently A			
Words include – verb types eg go, sleep – adjective types eg hot, big			
Uses some words to name a whole class of objects, eg uses 'car' for all vehicles, 'apple' for all fruit, 'mummy' for all women			
Combines words with pointing and reaching gestures to: – attract attention – ask for or comment on an object, eg 'mummy' + points at toy			
Uses words individually and in longer intonated vocalisations to: – comment on what's happening – ask simple questions/query – refer to non-present people or objects			
Has favourite 'words'/'phrases' that they use often, eg 'thatone'			

By the end of this stage
Children are regularly using a small vocabulary of words or signs and there is evidence of a steady increase in their understanding of language.

Stage B8

Stage B8 – English	Possibly	Definitely	What my child does and what it tells me; how I know my child can do this
Receptive language English			
Recognises and will identify many objects and pictures when named using speech			
Picks out two or more objects from a group of four, eg 'give me the cup and the doll', 'where's the...?'			
Understands simple questions/directions without accompanying gestures, eg fetch your shoes A			
Follows directions during play, eg 'feed teddy' A			
Expressive language English			
Uses up to 20 words: – names things and people – comments on what's happening – tells someone something – asks questions – responds to adult's questions/comments – protests – expresses likes and dislikes – describes actions			
Copies words overheard in conversation A			
Words used are more recognisable, but these may still be produced in a 'babyish' or 'immature fashion', eg 'goggy' for 'dog'			
Begins to make little sentences by joining two words together, eg daddy gone			
Uses a mixture of words/vocalisation/gesture (sometimes in very long utterances) to: – accompany play – express a range of meanings (though the exact meaning may be unclear)			

Level 2 check
Pragmatics, interaction, early words and meanings

	P	D
Uses their language for a range of different purposes		
Conversational turn-taking through language established		
Has 20+ words/signs recognisable to others		

Stage B9

Stage B9 – English	Possibly	Definitely	What my child does and what it tells me; how I know my child can do this
Receptive language English			
Recognises most common objects and pictures			
Understands familiar action words, eg 'sit down', 'come here', 'stop that'			
Understands more complex sentences, eg 'we are going to the shop now to buy some new shoes'			
Expressive language English			
Rapid growth in vocabulary – at least 50 words and becoming more difficult for parents to keep track of new words			
Uses more little sentences, eg 'daddy come', 'there it is', 'play with car', 'me got one'			
Refers to self by name			
Begins to use some pronouns 'I', 'me', 'you'			
Asks simple questions (two/three words plus intonation and/or quizzical face)			
Makes statements that: – provide information – comment on what the other speaker has just said			
Starts to know their own mind and expresses this, eg 'nowant bath', 'nogo bed'			

Level 2 check
Grammar

Uses an appropriate range of grammatical features at:	P	D
Clause level		
Phrase level		

By the end of this stage
Children have a large vocabulary and seem much more grown up because they are now able to use little sentences in conversation with their parents and others.

Stage B10

Stage B10 – English	Possibly	Definitely	What my child does and what it tells me; how I know my child can do this
Receptive language English			
Shows understanding of prepositions 'in', 'on'			
Some understanding of quantity, eg 'one/all'			
Understands size differences, eg big/small			
Will point to smaller parts of the body (eg chin, elbow, eyebrow) when told to do so			
Answers simple questions, eg 'how old are you?'			
Expressive language English			
Uses longer sentences (three to four words), eg 'mummy go shops now'			
Uses language to ask and find out about things			
Uses language during play and almost all activities			
Uses language to ask for help, eg washing hands, going to the toilet			
Uses different verb forms, eg 'play', 'played'			
Uses several pronouns correctly, 'I', 'me', 'you'			
Uses plurals, eg 'cats'			
Uses set phrases, eg 's mine', 'wanna/canna', without full understanding or use of the grammar			
Uses negatives 'no, 'not', 'no more'			
Uses over 200 words			
May repeat the first parts of words 'w-w-w-where doggie?'			

By the end of this stage
Children can understand most of what parents say, can use longer sentences and are starting to use more parts of grammar. They use language to express many different meanings. At this point in the child's development it is a good idea for parents and teachers of the deaf/speech and language therapists to use the Level 2 checklists again (Level 2 grammar, Level 2 pragmatics, Level 2 interaction) to check that the breadth of understanding and expression needed for future development has been established.

Stage B11

Stage B11 – English	Possibly	Definitely	What my child does and what it tells me; how I know my child can do this
Receptive language English			
Understands prepositions 'under', 'on top', 'behind', 'next to'			
Understands use of objects, eg 'what do we use to cut with?'			
Understands objects by description, eg 'wet', 'dirty'			
Understands all pronouns, eg 'they', 'he/she', 'him/her'			
Expressive language English			
Answers what, where and yes/no questions, eg 'what is she doing?', 'where is the dog?', 'is he running?'			
Retells a simple past event			
Uses several sentences linked with 'and'			
Uses a range of verb forms, eg 'play', 'playing', 'will play', 'played'			
Answers questions more fully, using two or more sentences, eg in response to 'tell me about your dog'			
Uses language for: – giving reasons – negotiating – playing with others – directing others – telling others about things			
Uses possessives, eg 'the boy's teddy'			
Retells a simple story – recalling events and characters			

Level 2 check
Grammar, pragmatic intentions, interaction

	P	D
Uses a range of grammatical features: – clause – phrase – word		
Uses their language for a range of different purposes, including early reasoning		
Conversational turn-taking through language established		

Appendix 14 Child X Sample Session Plans

Table A After 3 Months

Aim	Activity
Child X will imitate the Ling 6 Sounds through audition alone	Pick Up Sticks
Child X will request her turn using "My turn" 6 out of 8 times	Play dough Machine
Child X will comprehend food/drink vocabulary with 75% accuracy (e.g. *milk, juice, apple, orange, pear, biscuit*)	Having a Picnic: Real Food and Drink
Child X will comprehend 5 everyday phrases with 75% accuracy *(e.g. Bath time, I want the toilet, Sit down, Help me, Come on)*	Playmobil® House
Exposure to face parts *(e.g. eyes, nose, mouth, ears)*	Potato Head

Table B After 9 months

Aim	Activity
Child X will imitate the Ling 6 Sounds through audition alone	Magnetic Fruit
Child X will comprehend and use 2 key words (*noun + noun)* using familiar vocabulary with 75% accuracy	Pictures of People Barrier Game Person + food/drink
Exposure to new everyday phrases *(e.g. Wash your hands, Don't stand up, Where's your bag, Dinner)*	Toy objects, playhouse
Exposure to "Where"	Hide and seek game with her choice of objects
Comprehension and use of early action words *(e.g. cry, sleep, eat, kick, jump, blow)*	*Toy Play with objects*

Appendix 15 Child Y Sample Session Plans

Table A After 3 Months

Aim	Activity
Child Y will imitate the Ling 6 Sounds through audition alone	Babies in Play dough
Child Y will comprehend 2 key words *(e.g. Possessive noun + noun)* using familiar vocabulary with 75% accuracy	Pictures of Barrier Game Person + object (e.g. bag, coat, shoes, hat)
Exposure to new action words *(e.g. jump, kick, eat, sleep, cry)*	Props and pictures matching game
Exposure to Descriptive Words *(e.g. big, little, broken, hot)*	Lucky bag of things that relate to target descriptive words
Comprehension and Use of animal names	Barrier Game of animals and stamps See if Child Y can combine two animal names (*e.g.* "Make a cow *and dog*")

Table B After 9 months

Aim	Activity
Child Y will imitate the Ling 6 Sounds through audition alone	Sticker Collage
Child Y will expressively use 2 and 3 words using familiar vocabulary with 75% accuracy	Pictures of People Barrier Game *(noun + noun), (noun + verb)* *(noun + verb + object)*
Child Y will comprehend and use 2/3 colours with 75% accuracy	Colour game
Exposure to sequence story (4 part) using familiar vocabulary	Playmobil® toys
Comprehension of prepositions *(e.g. in, under)* with 75% accuracy	Matching Game of Objects using known key vocabulary

Appendix 16 Child X MacArthur-Bates CDI Results

Part I: Early Words

A. First Signs of Understanding

Before children begin to speak, they show signs of understanding language by responding to familiar words and phrases. Below are some common examples. Does your child do any of these?

		yes	no
1.	Respond when name is called (e.g., by turning and looking at source).	●	○
2.	Respond to "no no" (by stopping what he/she is doing, at least for a moment).	●	○
3.	React to "there's mommy/daddy" by looking around for them.	●	○

B. Phrases (28)

In the list below, please mark the phrases that your child seems to understand.

	understands		understands		understands		understands
Are you hungry?	●	Daddy's/mommy's home.	●	Give me a kiss.	●	Sit down.	●
Are you tired/sleepy?	●	Do you want more?	●	Go get ____.	○	Spit it out.	○
Be careful.	○	Don't do that.	●	Good girl/boy.	●	Stop it.	●
Be quiet.	●	Don't touch.	●	Hold still.	●	Time to go night night.	●
Clap your hands.	○	Get up.	●	Let's go bye bye.	●	Throw the ball.	●
Change diaper.	N/A	Give it to mommy.	●	Look/look here.	●	This little piggy. Twinkle Twinkle	●
Come here/come on.	●	Give me a hug.	○	Open your mouth.	○	Want to go for a ride?	●

C. Starting to Talk

		Never	Sometimes	Often
1.	Some children like to "parrot" or imitate things that they've just heard (including new words that they are just learning, and/or parts of sentences, for example, repeating "work now" after mother says "Mommy's going to work now.") How often does your child imitate words?	○	○	●
2.	Some children like to go around naming or labeling things, as though proud of knowing the names and wanting to show this. How often does your child do this?	○	●	○

D. Vocabulary Checklist

The following is a list of typical words in young children's vocabularies. For words your child understands but does not yet say, place a mark in the first column (understands). For words that your child not only understands but also uses, place a mark in the second column (understands and says). If your child uses a different pronunciation of a word (for example, "raffe" for "giraffe" or "sketti" for "spaghetti"), mark the word anyway. Remember, this is a "catalogue" of words that are used by many different children. Don't worry if your child knows only a few right now.

1. *Sound Effects and Animal Sounds* (12)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
baa baa	○	●	grrr	○	●	ouch Pow	○	●	vroom	○	●
choo choo	○	●	meow	○	●	quack quack	○	●	woof woof	○	●
cockadoodledoo hen noise	○	●	moo	○	●	uh oh	○	●	yum yum	○	●

2. *Animal Names (Real or Toy)* (36)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
animal	○	○	cow	○	●	goose	○	○	pig	○	●
bear teddy	○	○	deer	○	○	horse	○	○	pony	○	○
bee	●	○	dog	○	●	kitty	○	○	puppy	○	○
bird	○	●	donkey	○	●	lamb	○	○	sheep	○	●
bug	○	○	duck	○	○	lion	○	●	squirrel	○	○
bunny	○	●	elephant	●	○	monkey	○	●	teddy bear	○	●
butterfly says	○	○	fish	○	●	mouse	○	●	tiger	○	○
cat	○	●	frog	○	○	owl	○	●	turkey	○	○
chicken	●	○	giraffe	○	○	penguin	○	○	turtle	○	○

3. *Vehicles (Real or Toy)* (9)

	understands	understands and says		understands	understands and says		understands	understands and says
airplane	○	●	car	○	●	stroller push	○	●
bicycle	○	●	firetruck	○	○	train	○	●
bus	●	○	motorcycle	○	○	truck	○	○

4. *Toys* (8)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
ball	○	●	block	○	○	bubbles	●	○	pen colours	○	○
balloon	○	●	book	○	●	doll baby	○	●	toy	○	○

5. *Food and Drink* (30)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
apple	○	●	weetabix	●	○	fish	○	●	peas	○	○
banana	○	●	cheese	○	○	food	○	●	pizza	○	●
bread	●	○	chicken	●	○	ice cream	●	○	raisin	○	○
butter	○	○	coffee	○	○	juice	○	●	spaghetti	○	○
cake	○	●	cookie biscuit	○	●	meat	○	○	~~toast~~ sandwich	○	●
candy	○	○	cracker	○	○	milk	○	●	water	○	●
carrots	○	○	drink	○	●	noodles	○	○			
cereal	○	○	egg	○	●	orange	○	●			
pear		●									

6. *Clothing* (19)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
beads	○	○	diaper	○	○	necklace	○	○	shorts	○	○
bib	○	○	dress	○	○	pajamas	○	○	sock	○	●
boots	○	○	hat	○	●	pants	○	○	sweater	○	○
button	○	●	jacket	○	○	shirt	○	○	zipper	○	○
coat	○	●	jeans	○	○	shoe	○	●	bag		●

7. *Body Parts* (20)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
arm	○	●	face	●	○	head	○	●	owie/boo boo	○	○
belly button	○	○	foot	○	○	knee	○	○	tooth teeth	○	●
cheek	○	○	finger	○	○	leg	○	○	toe	○	○
ear	○	●	hair	○	●	mouth	○	●	tongue	○	●
eye	○	●	hand	○	●	nose	○	●	tummy	○	○

8. *Furniture and Rooms* (24)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
toilet bathroom	○	●	crib	○	○	living room	○	○	sink	○	○
bathtub	○	○	door	○	●	oven	○	○	stairs	●	○
bed	○	●	drawer	○	○	play pen	○	○	stove	○	○
bedroom	●	○	garage	○	○	~~potty~~ toilet	○	●	table	○	●
chair	○	●	high chair	○	○	refrigerator	○	○	TV	○	●
couch	○	○	kitchen	●	●	rocking chair	○	○	window	○	●

9. *Small Household Items* (36)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
blanket	●	○	dish	○	○	money	●	○	scissors	○	●
bottle	○	●	fork	●	○	paper	○	●	soap	○	○
bowl	●	○	glass	○	●	penny	○	○	spoon	○	●
box	●	○	glasses	○	○	picture	○	○	telephone	●	○
broom	○	○	hammer	○	○	pillow	○	○	~~tooth~~brush	○	●
brush	○	●	keys	○	●	plant	○	○	towel	●	○
clock tick tock	○	●	lamp	○	○	plate	●	○	trash bin	○	○
comb	○	○	light	○	●	purse	○	○	vacuum	●	○
cup	○	●	medicine	○	○	radio	○	○	watch tick tock	○	○

10. *Outside Things and Places to Go* (27)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
backyard	○	○	moon	○	●	school	○	●	sun	○	○
beach	○	○	outside	●	○	shovel	○	○	swing	○	○
church*	○	○	park	○	●	sky	○	○	tree	○	●
flower	●	○	party	○	○	slide up up whee	○	●	water	○	●
garden	○	○	pool	○	○	snow	○	○	work	●	○
home	○	●	rain	○	●	star	○	●	zoo	○	○
house	○	●	rock	○	○	store	○	○	roundround round		●

*or word used in your family

11. *People* (20)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
aunt	○	○	brother	○	○	grandpa*	○	○	people	○	○
baby	○	●	child	○	○	lady	○	●	person	○	○
babysitter	○	○	daddy* papa	○	●	man	○	○	sister	○	○
babysitter's name	○	○	girl	○	●	mommy* mummy mama	○	●	teacher nene	○	●
boy	○	●	grandma* nana	○	●	child's own name	○	●	uncle	○	○

*or word used in your family

12. *Games and Routines* (19)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
bath	●	○	hello	○	●	no	○	●	thank you	○	●
breakfast	○	○	hi	○	●	patty cake	○	○	wait	●	○
bye or bye bye	○	●	lunch	○	○	peekaboo	○	○	wanna/want to more	○	●
dinner	●	○	nap	○	○	please	○	●	yes	○	●
don't	●	●	night night	○	●	shh/shush/hush	○	●			

13. *Action Words* (55)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
bite	●	○	bump	○	○	dance	●	○	eat signs	○	○
blow	○	●	clean	○	○	draw painting	○	●	fall	○	○
break	○	○	close	●	○	drink	○	●	feed	○	○
bring	○	○	cry	○	●	drive	○	○	finish all gone	○	●

(contin

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
get	○	○	look	●	○	say	○	○	take	○	○
give	○	○	love	○	●	see	●	○	throw	●	○
go	○	●	open	○	●	show	○	○	tickle	●	○
help	○	●	play	●	○	sing	●	○	touch	○	○
hit	○	○	pull	○	●	sleep	●	○	watch	○	○
hug	●	○	push	○	●	smile happy	○	○	walk	○	●
hurry	○	○	put	○	○	splash	○	○	wash	○	●
jump	○	●	read	○	○	stop	○	●	wipe	○	○
kick	○	○	ride	○	○	swim	○	○	write	○	○
kiss	●	○	run	●	○	swing	○	○			
						tidy up		●			

14. *Words About Time* (8)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
day	○	○	morning	○	○	now	○	○	tomorrow	○	○
later	○	○	night	○	○	today	○	○	tonight	○	○

15. *Descriptive Words* (37)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
all gone	○	●	dark	○	○	hot	○	●	sick	○	○
asleep gesture	○	○	dirty	●	○	hungry	○	○	sleepy	○	○
bad	○	○	dry	○	●	hurt pain	○	●	soft	○	○
big	○	●	empty	○	○	little small	●	●	thirsty	○	○
blue	○	●	fast	○	○	naughty	●	○	tired	○	○
broken	○	○	fine	○	○	nice	○	●	wet	○	●
careful	○	○	gentle	○	○	old	○	○	yucky	○	●
clean	○	○	good	○	●	pretty	○	○			
cold	○	●	happy	○	●	red	○	●			
cute	○	○	hard	○	○	scared signs	○	○			

16. *Pronouns* (11)

	under-stands	under-stands and says		under-stands	under-stands and says		under-stands	under-stands and says		under-stands	unc sta and
his	○	○	it	○	○	my	○	○	you	○	○
her	○	○	me	○	○	that	○	○	your	○	○
I	○	○	mine	○	●	this	○	○		○	○

17. *Question Words* (6)

	under-stands	under-stands and says		under-stands	under-stands and says		under-stands	unc sta and
how	○	○	when	○	○	who	○	○
what	○	○	where	○	○	why	○	○

18. *Prepositions and Locations* (11)

	under-stands	unc stands and says		under-stands	under-stands and says		under-stands	under-stands and says		under-stands	unc sta and
away	○	○	in	○	○	on	○	○	under	○	○
back	○	○	inside	○	○	out	○	●	up	○	●
down	●	○	off	○	○	there	○	○			

19. *Quantifiers* (8)

	under-stands	under-stands and says		under-stands	under-stands and says		under-stands	under-stands and says		under-stands	uno sta and
all	○	○	more	○	●	not	○	○	same	○	○
another	○	○	none	○	○	other	○	○	some	○	○

Appendix 17 Child Y MacArthur-Bates CDI Results

B. Phrases (28)

In the list below, please mark the phrases that your child seems to understand.

	understands		understands		understands		understands
Are you hungry?	●	Daddy's/mommy's home.	●	Give me a kiss.	●	Sit down.	●
Are you tired/sleepy?	●	Do you want more?	●	Go get ___.	●	Spit it out.	●
Be careful.	●	Don't do that.	●	Good girl/boy.	●	Stop it.	●
Be quiet.	●	Don't touch.	●	Hold still.	●	Time to go night night.	●
Clap your hands.	●	Get up.	●	Let's go bye bye.	●	Throw the ball.	●
Change diaper. N/A	○	Give it to mommy.	●	Look/look here.	●	This little piggy.	●
Come here/come on.	●	Give me a hug.	●	Open your mouth.	●	Want to go for a ride?	●

C. Starting to Talk

		Never	Sometimes	Often
1.	Some children like to "parrot" or imitate things that they've just heard (including new words that they are just learning, and/or parts of sentences, for example, repeating "work now" after mother says "Mommy's going to work now.") How often does your child imitate words?	○	●	○
2.	Some children like to go around naming or labeling things, as though proud of knowing the names and wanting to show this. How often does your child do this?	○	○	●

D. Vocabulary Checklist

The following is a list of typical words in young children's vocabularies. For words your child understands but does not yet say, place a mark in the first column (understands). For words that your child not only understands but also uses, place a mark in the second column (understands and says). If your child uses a different pronunciation of a word (for example, "raffe" for "giraffe" or "sketti" for "spaghetti"), mark the word anyway. Remember, this is a "catalogue" of words that are used by many different children. Don't worry if your child knows only a few right now.

1. *Sound Effects and Animal Sounds* (12)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
baa baa	○	●	grrr	○	●	ouch	○	●	vroom	○	●
choo choo	○	●	meow	○	●	quack quack	○	●	woof woof	○	●
cockadoodledoo	●	○	moo	○	●	uh oh	○	●	yum yum	○	●

2. *Animal Names (Real or Toy)* (36)

	under-stands	under-stands and says		under-stands	under-stands and says		under-stands	under-stands and says		under-stands	under-stands and says
animal			cow			goose			pig		
bear			deer			horse			pony		
bee			dog			kitty			puppy		
bird			donkey			lamb			sheep		
bug			duck			lion			squirrel		
bunny			elephant			monkey			teddy bear		
butterfly			fish			mouse			tiger		
cat			frog			owl			turkey		
chicken			giraffe			penguin			turtle		

3. *Vehicles (Real or Toy)* (9)

	under-stands	under-stands and says		under-stands	under-stands and says		under-stands	under-stands and says
airplane			car			stroller pram		
bicycle bike			firetruck engine			train		
bus			motorcycle			truck		

4. *Toys* (8)

	under-stands	under-stands and says		under-stands	under-stands and says		under-stands	under-stands and says		under-stands	under-stands and says
ball			block			bubbles			pen		
balloon			book			doll			toy		

5. *Food and Drink* (30)

	under-stands	under-stands and says		under-stands	under-stands and says		under-stands	under-stands and says		under-stands	under-stands and says
apple			cheerios			fish			peas		
banana			cheese			food			pizza		
bread			chicken			ice cream			raisin		
butter			coffee			juice			spaghetti		
cake			cookie			meat			toast		
candy sweet			cracker			milk			water		
carrots			drink			noodles					
cereal			egg			orange					

6. *Clothing* (19)

	understands	understands and says
beads	○	○
bib	○	○
boots	○	●
button	●	○
coat	○	●
diaper	○	○
dress	○	●
hat	○	●
jacket	○	○
jeans	○	●
necklace	○	○
pajamas	○	○
pants	○	●
shirt	○	●
shoe	○	●
shorts	○	○
sock	○	●
sweater	●	○
zipper	○	●

7. *Body Parts* (20)

	understands	understands and says
arm	○	●
belly button	●	○
cheek	●	○
ear	○	●
eye	○	●
face	○	●
foot	○	○
finger	○	●
hair	○	●
hand	○	●
head	○	●
knee	○	○
leg	○	●
mouth	○	●
nose	○	●
owie/boo boo	○	○
tooth	○	●
toe	○	○
tongue	○	○
tummy	○	○

8. *Furniture and Rooms* (24)

	understands	understands and says
bathroom	○	○
bathtub bath	○	●
bed	○	●
bedroom	○	
chair	○	●
couch	○	
crib cot	○	●
door	○	●
drawer	○	○
garage	○	○
high chair	●	○
kitchen	○	●
living room	●	○
oven	○	○
play pen	○	○
potty	●	○
refrigerator fridge	●	○
rocking chair	●	○
sink	○	○
stairs	○	●
stove hob	●	○
table	○	●
TV	○	●
window	○	●

9. *Small Household Items* (36)

	understands	understands and says
blanket	●	○
bottle	○	●
bowl	○	
box	○	○
broom	●	○
brush	○	●
clock	○	
comb	○	○
cup	○	●
dish	○	
fork	○	●
glass	○	
glasses	○	●
hammer	○	
keys	○	●
lamp	○	
light	○	●
medicine	●	○
money	○	●
paper	○	●
penny	●	
picture	○	○
pillow	○	○
plant	○	○
plate	○	●
purse	●	○
radio	○	○
scissors	○	●
soap	○	●
spoon	○	●
telephone	○	●
toothbrush	○	●
towel	○	○
trash bin	○	●
vacuum hoover	○	●
watch	○	

10. *Outside Things and Places to Go* (27)

	understands	understands and says		understands	understands and says		understands	understands and says		understands
backyard	○	○	moon	○		school	○	●	sun	○
beach	○	○	outside	○	●	shovel	○	○	swing	○
church*	○	○	park	○	●	sky	○	●	tree	○
flower	○	●	party	○	●	slide	○	●	water	○
garden	○	●	pool	●	○	snow	○	●	work	○
home	○	○	rain	○	●	star	○	●	zoo	○
house	○	●	rock	●	○	store shop	○	●		

*or word used in your family

11. *People* (20)

	understands	understands and says		understands	understands and says		understands	understands and says		understands
aunt	○	○	brother	○	●	grandpa*	○		people	
baby	○	●	child	○	○	lady	○	●	person	○
babysitter	○	○	daddy*	○	●	man	○	○	sister	○
babysitter's name	○		girl	○	●	mommy*	○	●	teacher	○
boy	○	●	grandma*	○		child's own name	○	●	uncle	○

*or word used in your family

12. *Games and Routines* (19)

	understands	understands and says		understands	understands and says		understands	understands and says		understands
bath	○	●	hello	○	●	no	○	●	thank you	○
breakfast	○	●	hi	○		patty cake	●	○	wait	○
bye or bye bye	○	●	lunch	○	●	peekaboo	○	●	wanna/want to	○
dinner	○	●	nap		○	please	○	●	yes	○
don't	○	●	night night	○	●	shh/shush/hush	○	●		

13. *Action Words* (55)

	understands	understands and says		understands	understands and says		understands	understands and says		understands
bite	○	●	bump	○		dance	○	●	eat	○
blow	○	●	clean	○	●	draw	○	●	fall	○
break	●	○	close	○	○	drink	○	●	feed	○
bring	●	○	cry	○	●	drive	○	○	finish	○

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
get			look			say			take		
give*			love*			see*			throw		
go			open			show			tickle		
help			play			sing*			touch		
hit			pull			sleep			watch		
hug			push			smile			walk		
hurry			put			splash			wash		
jump			read			stop			wipe		
kick			ride			swim			write		
kiss			run			swing					

14. *Words About Time* (8)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
day			morning			now			tomorrow		
later			night			today			tonight		

15. *Descriptive Words* (37)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
all gone			dark			hot			sick		
asleep			dirty			hungry			sleepy		
bad			dry			hurt			soft		
big			empty			little			thirsty		
blue			fast			naughty			tired		
broken			fine			nice			wet		
careful			gentle			old			yucky		
clean			good			pretty					
cold			happy			red					
cute			hard			scared					

Appendix 18 Journal Article

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The strengths and weaknesses in verbal short-term memory and visual working memory in children with hearing impairment and additional language learning difficulties

Suzi Willis *, Juliet Goldbart, Jois Stansfield

Health Professions Department, Speech Pathology & Therapy, Manchester Metropolitan University, Manchester, UK

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ABSTRACT

Objectives: To compare verbal short-term memory and visual working memory abilities of six children with congenital hearing-impairment identified as having significant language learning difficulties with normative data from typically hearing children using standardized memory assessments.

Methods: Six children with hearing loss aged 8–15 years were assessed on measures of verbal short-term memory (Non-word and word recall) and visual working memory annually over a two year period. All children had cognitive abilities within normal limits and used spoken language as the primary mode of communication. The language assessment scores at the beginning of the study revealed that all six participants exhibited delays of two years or more on standardized assessments of receptive and expressive vocabulary and spoken language.

Results: The children with hearing-impairment scores were significantly higher on the non-word recall task than the "real" word recall task. They also exhibited significantly higher scores on visual working memory than those of the age-matched sample from the standardized memory assessment.

Conclusions: Each of the six participants in this study displayed the same pattern of strengths and weaknesses in verbal short-term memory and visual working memory despite their very different chronological ages. The children's poor ability to recall single syllable words in relation to non-words is a clinical indicator of their difficulties in verbal short-term memory. However, the children with hearing-impairment do not display generalized processing difficulties and indeed demonstrate strengths in visual working memory. The poor ability to recall words, in combination with difficulties with early word learning may be indicators of children with hearing-impairment who will struggle to develop spoken language equal to that of their normally hearing peers. This early identification has the potential to allow for target specific intervention that may remediate their difficulties.

Introduction

There are between one and three children per 1000 live births each year in the UK who are diagnosed with permanent congenital hearing loss [1]. It is well known that hearing loss causes speech and language delays [2]. Digital hearing aids and cochlear implants (CI) have now made it possible for many children with severe and profound hearing loss to acquire age appropriate spoken language after initial, expected language delay of approximately three to four years [3,4]. Historically, research attributed the variability in spoken language outcomes for children using cochlear implants (CI) to factors such as age of implant, communication mode, and family support [3–9]. There is a proportion of children with hearing-impairment (HI) that exhibit delays in both receptive and expressive spoken language, even after several years of device use and intensive support from professionals and parents [10–13]. Even in ideal circumstances, of very early fitting of hearing aids or cochlear implants and the involvement of educated parents, there is a proportion of children with HI who still do not achieve spoken language commensurate with peers by the age of 4.5 years [12].

* Corresponding author at: Speech Pathology & Therapy, Elizabeth Gaskell Campus, Manchester Metropolitan University, Hathersage Road, Manchester M13 0JA, UK. Tel.: +44 01612474639.
E-mail address: s.willis@mmu.ac.uk (S. Willis).

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These deficits in language can have long term effects on the children's ability to access the curriculum, as well as their development of literacy skills [14].

It is hypothesized that, the early deprivation of auditory input that children with HI experience may have negative impact upon their development of verbal memory and adversely affect their spoken language learning [15]. It is commonly recognized that deficits in memory can have long-term effects on school performance [16]. Researchers are exploring the relationship between short-term memory (STM), working memory (WM) and spoken language abilities in children with hearing-impairment, as one possible explanation for the large individual variations in paediatric outcomes [17–21].

Working memory

Working memory (WM) is defined as the temporary storage and manipulation of either verbal or visual information. It acts as a workbench or mental workspace for information that requires immediate attention and processing. The most influential model of working memory is that of Baddeley [22]. Baddeley's model comprises the central executive, the two modality-specific subsystems (e.g. the phonological loop and visuo-spatial sketch-pad) and the episodic buffer, which is defined as "the multidimensional storage system" [22] (p.189). The phonological loop's function is that of interpreting phonological information and creating temporary phonological representations that begin to decay after approximately 2 s. The function of the phonological loop is to support word learning and vocabulary development. The visuo-spatial sketch pad's role is similar to that of the phonological loop, but in relation to visual and spatial information. The episodic buffer provides temporary storage of information and integrates information from the phonological loop and visuo-spatial sketch pad. The central executive is involved in processing and co-ordinating information from either sub system. It is a component involved in working memory, but not short-term memory (STM).

Assessing STM/Phonological loop

It is commonly recognized that limitations in the amount of information that can be held and manipulated in the STM or WM can negatively affect linguistic functioning and educational achievement [16]. The inability to retain instructions long enough to act upon them in a classroom situation will inevitably affect a child's ability to function and achieve national curriculum targets equal to that of their peers. Non-word repetition is often utilized to evaluate the integrity of the phonological loop and the functioning of verbal short-term memory [23]. The most frequently utilized non-word repetition tests are the Children's Test of Non-word Repetition (CNRep) [24], Non-word Repetition Test (NRT) [25] and subtests from a Developmental Neuropsychological Assessment (NEPSY) [26]. These assessments ask listeners to repeat nonsense words (from audition alone) that increase in syllable length. The inability to correctly repeat multisyllabic nonsense words of three or more syllables is considered a reliable marker of language impairment in early childhood [27]. The Working Memory Test Battery for Children (WMTB-C) [28] is also an assessment that measures verbal and visual STM and WM. It contains specific subtests that evaluate the functioning and integrity of the phonological loop, visual-spatial sketch pad and the central executive. Forward digit recall also evaluates the functioning of the phonological loop and is commonly recognized as being significantly correlated with vocabulary development and language acquisition. However, numbers themselves are extremely familiar and may not accurately evaluate phonological STM [24]. The use of non-words in a verbal STM assessment task evaluates phonological storage capacity and access to long-term memory. This process is similar to what young language learners face in their acquisition of new vocabulary.

Cochlear implant research and memory

It has been hypothesized that the delayed and degraded signal that children receive via hearing aids or cochlear implant (CI) has a detrimental effect on word learning and memory and results in unclear phonological representations [18]. A number of researchers have investigated this hypothesis in their research and utilized traditional non-word repetition tests, as a way in which to identify weakness in phonological short-term memory in children with HI [15,20,29,30]. The performance on the multisyllabic non-word repetition task correlates highly with working memory, reading, and receptive vocabulary abilities in children with HI [30–32]. Lina-Granade et al. [20] reported, in their study of 17 CI users aged from 7–16 years, that working memory is also strongly correlated with language development and that deficits in working memory may be as a result of delayed auditory input as an infant or as a result of the hearing-impairment itself.

In addition, researchers also acknowledge that there may be a correlation between verbal rehearsal, working memory and linguistic achievement [33]. The process of rehearsal is said to be another accurate way in which to measure the efficiency and ability of phonological representations to be maintained in the STM. In an early study, Pisoni & Cleary [29] reported that verbal rehearsal speed was positively correlated with spoken language outcomes in 180 children who were CI users, aged between 8 and 9 years old. In a follow up study, Pisoni et al. [18] again utilized digit recall (forward & backward) and verbal rehearsal speed with 108 adolescent CI users, 10 years after their initial study. The population of adolescents who attended for the follow-up study after 10 years exhibited significantly higher scores in their speech perception, speech intelligibility and language scores than that of the 72 non-returning adolescents. Pisoni et al. [18] found that forward digit span and verbal rehearsal speed at ages 8–9 were positively correlated with future linguistic functioning in the high school years. In both of the above studies, the paediatric CI users used either spoken language (oral) or spoken language and signed language (total communication). It is worthy of note that even those CI users who achieved age appropriate language still demonstrated a weakness in STM abilities and verbal rehearsal. It would be of interest to examine the proportion of these CI users who had received their CI by the age of two and were orally educated, and exhibited language impairment and poor verbal STM.

There are few studies which have specifically targeted the population of CI children with additional language learning difficulties. Hawker et al. [34] focused upon CI users who displayed significant language learning difficulties and compared them to other CI users. The researchers paired six paediatric CI users with disproportionate language impairment with CI peers whose language development followed a more typical developmental trajectory. The CI children were matched on aetiology, age of implantation and CI experience. Hawker et al. [34] found that non-word repetition (using NEPSY non-word repetition subtest), [26] was an area of weakness for both the Control CI group and the CI group with disproportionate language impairment (DLI). They concluded that all six DLI-CI users had severe language impairment and phonological short-term memory difficulties and that the control group exhibited characteristics similar to children with specific language impairment. This study did not investigate visual memory, which would have demonstrated whether this population of children with HI exhibited generalized processing difficulties. Wass et al.'s [35] study of 34 CI children, aged between 5;7 and 13;14 considered visual memory and found that memory difficulties existed in verbal STM, but not in visual WM. It is important to gain a greater understanding of the memory abilities in the population of hearing aid and CI users who have not achieved linguistic competence equal to that of their typically hearing peers despite long-term use of their hearing aids or CI.

The clinical implications of the research findings in the field of hearing-impairment and working memory have initially focused upon training programmes to strengthen verbal STM and working memory. Kronenberger et al. [36] targeted nine paediatric CI users in their study, which investigated the feasibility and efficacy of a working memory training programme over a 5 week period. While there was a small improvement in verbal STM at the one-month review, this development was not sustained beyond the initial phase of the study. Sentence repetition, however, continued to show improvement 6 months post intervention. By developing a greater understanding of HI children's strengths and weakness in visual and verbal memory, clinicians may be better able to identify the population of DHH children who have language learning difficulties earlier, as well as provide more appropriate intervention to meet their needs.

Aims of the current study

The purpose of this study was to compare the performance of six typically developing children with HI, who have severe language learning difficulties, with normative data from hearing children, using standardized memory assessments over a two-year period. The current phase of research is part of a longitudinal study exploring the language and memory profiles of a typical language learners with hearing-impairment. The findings from the first year of the study, with regard to the children's memory abilities, were presented at the 13th European Symposium in Paediatric Cochlear Implants (2011). The study makes use of a novel, memory test battery that evaluates verbal STM, using both words and non-words and comparing these results with each other and the children's visual WM abilities. The different manner in which the current study evaluates verbal STM and the function of the phonological loop has not been previously utilized with children with HI, and the findings may highlight deficits in memory abilities that have gone undetected.

The key research questions for the current study were:

- What verbal short-term memory profiles do the participants exhibit?
- Does this population of children with HI display any strengths or weaknesses in visual working memory relative to normative data?
- Are there generalized memory and processing deficits in this sub-group of children with HI?
- As a group, are there distinct patterns of strengths and weaknesses in visual working memory or verbal short-term memory?

Methods

Recruitment

The participants were recruited from educational authorities in the North of England where children with HI are educated in a mainstream school or from a school for children with HI (see Table 1). These educational placements represent the environment in which the majority of children with HI are educated. The specialist teachers/teachers of the hearing-impaired acted as gatekeepers and disseminated the parent information sheets.

Table 1
Demographics of children.

Child	Gender	Device & type of hearing loss	Age at testing	Educational environment	Access to speech from 250 Hz–4000 Hz when aided/CI
A	Male	HA severe loss[a]	8;5	Mainstream	Yes
B	Female	CI profound loss[b]	14;11	Mainstream	Yes
C	Male	CI sloping severe to profound loss[b]	9;9	School for hearing impaired	Yes
D	Male	HA severe loss[a]	10;3	School for hearing impaired	Yes
E	Female	HA moderate/severe loss[a]	9;11	Mainstream	Yes
F	Male	CI severe/profound loss[b]	9;4	School for hearing impaired	Yes

[a] HA = Hearing Aid User.
[b] CI = Cochlear Implant User.

Purposive sampling was utilized, as teachers of the HI identified those children from their caseload who were experiencing significant difficulties in learning spoken language in addition to their HI. The wide age range of participants with HI enabled comparison of language and memory abilities across ages, as well as the possibility of identifying possible patterns of difficulties that occurred in this population of children irrespective of chronological age.

Participants

The participants were six children/adolescents with congenital, bilateral, sensorineural hearing-impairment, who had been fitted with hearing aids by the age of one and transitioned to a unilateral cochlear implant, where appropriate, prior to the age of 30 months. Participants were aged between 8 and 15 years with cognitive abilities within normal limits. All the children/adolescents used spoken language as their primary mode of communication and english was the only language used in the home environment. The children were consistent users of their binaural hearing aids or cochlear implant and were able to access speech across the speech frequencies at quiet levels when wearing their equipment. The children all exhibited significant difficulties in developing spoken language and were functioning at least two years behind their chronological age, or at least one standard deviation below the mean, on receptive and expressive vocabulary and language assessments (Table 2). Three participants were based in a mainstream school, while the other three participants attended

Table 2
Initial standard scores for language and vocabulary assessments for all children.

Child	Expressive vocabulary EVT2[a]	Receptive vocabulary BPVS 2[a]	Expressive/Memory CELF 4: sentence recall[b]	Expressive CELF-4: sentence formulation[b]
A	70	66	3	2
B	80	65	1	1
C	69	66	1	1
D	77	71	1	1
E	77	66	2	1
F	76	71	1	1

[a] Standard Score <85 is at least one standard deviation below the mean.
[b] Standard Score of <7 is at least one standard deviation below the mean.

a school for children with hearing-impairment (Table 1). All six children were able to perceive speech across the speech frequencies when wearing their equipment. All children received regular input from their local specialist teacher of the hearing-impaired and a speech and language therapist.

Procedure and materials

Annual administration, over a two year period, of subtests from standardized memory assessments from the Working Memory Test Battery for children (WMTB-C) [28] and Automated Working Memory Assessment (AWMA) [37] was used to evaluate verbal (STM) and visual (WM) over a two year period. Two different subtests from the WMTB-C were used to evaluate verbal short-term memory (STM), and one subtest from the AWMA was utilized to assess visual working memory (WM). The participant's scores were compared with normative data from the standardized assessment from typically hearing children.

Ethical approval for this study was obtained from the authors' university ethics committee, a local National Health Service Research Ethics Committee and National Health Service Research & Development Department, reference number 09/H1008/109. The parents of participants were provided with a summary of the study results via written information. Parents were encouraged to contact the researcher to ask any questions and engage in a discussion of the results with reference to their child. Parental consent was obtained for each child, as well as assent from older participants.

Testing

All children involved in the study were visited in their local primary schools. The standardized memory assessments were administered to the children by the first author in a quiet room, within the school environment, according to testing instructions. The instructions and assessment stimuli were presented using live voice by the first author who was a qualified speech & language therapist, highly experienced in working with paediatric hearing aid and cochlear implant users. The Ling Sounds [38] were presented via audition alone prior to each session to check the children's speech perception. This Ling Sounds task asks children with HI to repeat speech sounds across the speech frequencies (i.e. "ah", "oo", "ee","sh", "s", and "m") through listening alone, in order for the clinician to verify that the child's equipment is working to specification. This task also reaffirms that the child is able to clearly hear and understand the instructions and stimuli during the assessment. The testing session lasted no more than 30 min and was video recorded. The word recall subtest was administered first, then the non-word recall subtest and finally the odd-one out subtest. In order to avoid fatigue, incidental conversation took place and children were asked if they "needed a break." None of the children in this study required a rest during the administration of the memory tests.

Verbal short-term memory tests

The word recall and non-word recall subtests from the WMTB-C [28] assess the functioning of the phonological loop. The word recall subtest asks children to correctly, recall single syllable words in the same order that they are presented. The words are consonant-vowel-consonant (CVC) in structure. The non-word recall subtest follows the same procedure and the items have the same CVC structure as the "real" words. Each of these tests are administered in their entirety, before moving onto the next test. No repetitions are allowed in either of the subtests. The non-word recall task on the WMTB-C addresses the possible confounding variable of oro-motor weakness in that the non-word task asks children to repeat single syllable, CVC nonsense words, instead of multi-syllabic nonsense words. The children were asked to "please listen carefully to the words/non-words that I am going to say and then repeat them exactly as I have said them in the same order." The tasks increase in complexity, as children are required to recall four targets (i.e. either words or non-words) correctly in each subgroup of either two, three or four words or non-words. The subtest ceases when the child cannot correctly imitate four targets within a subgroup. The manual provides administrators with rhyming words of the target non-words in order to increase the reliability of presentation. The manual reported the inter-tester reliability for the non-word recall subtest as .86–.90. The standardization information states that the test–retest reliability coefficients are .80 for 5–8 years old and .64 for 9.5–11.5 years old in the Word recall subtest. They are .68 for 5–8 years old and .43 for 9.5–11.5 years old for the non-word test.

Visual working memory test

The odd-one out subtest is a visuo-spatial working memory (WM) subtest from the AWMA [37]. This test assesses a child's ability to simultaneously remember visual information whilst also manipulating and processing it. Success at this task involves the functioning of the central executive [22,39]. The visual WM task specifically evaluated visual spatial WM using shapes without an identifiable name, which meant that the task did not rely upon phonological encoding in order for it to be completed. The odd-one out subtest asks the child to recall the "odd one out" of a group of three shapes presented horizontally on the screen. The child is asked to "point to the shape that does not match the other two and remember where it was located on the computer screen." At the end of each presentation of shapes, the screen becomes blank. The child must identify the location of the "odd" shapes in the correct order. The participant must complete this task four times to move onto the next subgroup. Again this task increases in complexity, as children need to recall more shapes (2, 3, 4, 5) if they are successful at a previous level. The test–retest reliability for the standardization population of this subtest is .88.

Analysis

Descriptive statistics, using standardized scores were utilized to analyse data in conjunction with SPSS 19. Group differences between the normative sample and study group were examined using standardized scores. Standardized scores were also used when conducting *t*-tests and repeated measures analysis of variance from each of the standardized memory assessments. These analyses examined the change in memory and profiles over time for the children as individuals and as a group.

Results

What verbal short-term memory profiles do the participants exhibit?

The mean and standard deviation scores for the word recall subtest and the non-word recall subtest, which measure verbal STM are shown in Table 3. In both year 1 and year 2 of the study, as a

Table 3
Mean standard scores & standard deviation memory assessments for the group as a whole ($N = 6$)

Test	Year	Mean	N	Std. deviation	Std. error mean
Word Recall	1	81.67	6	12.48	5.10
Non-Word	1	110.00	6	10.66	4.35
Word Recall	2	80.00	6	13.19	5.90
Non-Word	2	108.60	6	11.28	5.05
Visual WM	1	112.00	6	6.23	2.55
Visual WM	2	118.00	6	10.45	4.27

Standard Score <85 is at least one standard deviation below the mean.

Table 4
Word recall and non-word recall *t*-tests $p = .010$ (two tailed).

	Mean difference	Std. deviation	Std. error mean	95% Confidence interval		t	df	Sig. (2-tailed)
				Lower	upper			
Pair 1 Word recall Year2 Non-word recall year 2	−25.00	±15.67	6.39	−41.94	−9.06	−3.99	5	.010
Pair 2 Word recall year1 Non-word recall Year1	−28.33	±12.23	4.99	−41.16	−15.503	−5.68	5	.002

group the children with HI performed at least one standard deviation below the mean (<85) on the word recall task.

A *t*-test was conducted using standard scores to test for a significant difference between the word recall and non-word recall means in both years of the study. Table 4 shows that participants performed significantly better on the non-word task than the word task in both years 1 and 2, $p = .010$ (two tailed). In order to examine the overall differences between word recall and non-word recall a one-way an analysis of variance was conducted on the data and a significant effect was observed, *F* value of 29.767, $p = .003$. The post hoc (Bonferroni) test revealed a significant main effect for word recall versus non-word recall regardless of the year.

Does this population of children display any strengths or weaknesses in verbal short-term memory (STM) visual working memory (WM)?

Fig. 1 represents the distribution of standard scores for year 1 and year 2 on the short-term memory and visual working memory tasks. It is apparent that in both the first and second year of the study, word recall standard scores were significantly lower than non-word recall standard scores and that visual WM abilities were also greater for the children with HI than the normative data.

Are there generalized memory and processing deficits in this population of children with HI?

A *t*-test was conducted using standard scores to test for a significant difference between the HI participants visual WM and that of the normative data in both years of the study. Table 5 shows that participants performed significantly better on the visual working memory tasks from AWMA test than the normative sample of normally hearing peers in both years 1 and 2 of the study ($M = 112$ in Year 1 and $M = 118$ in Year 2); $p = .008$ (two tailed). The results of the visual WM tests highlight that there are no generalized processing difficulties with this group of children with HI.

As a group, are there distinct patterns of strengths and weaknesses in visual working memory or verbal short-term memory?

Table 6 summarizes the standard scores for the three memory tests for individual participants. It also identifies the children with HI who are performing at least one standard deviation below the mean in relation to their typically hearing peers (standard score <85). All six participants achieved standard scores on the visual WM task that were greater than the normative data of hearing

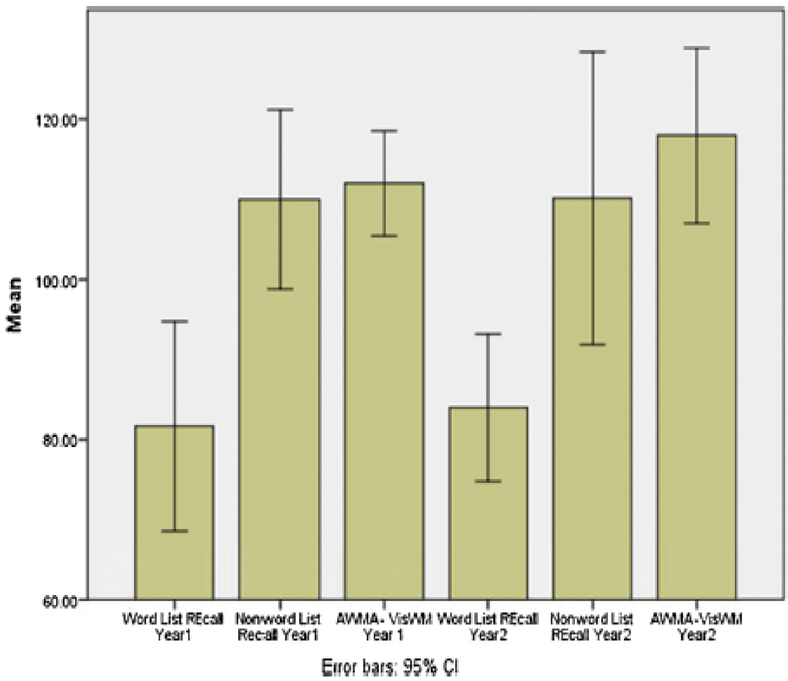

Fig. 1. Year 1 & 2 mean standard scores for word recall & non-word recall & visual WM assessments (Standard score <85 is at least one standard deviation below the mean).

Table 5
Visual working memory *t*-tests $p = .008$ (two tailed).

	Mean difference	95% Confidence interval		*t*	*f*	Sig. (2-tailed)
		Lower	Upper			
Visual WM (Odd one out) Year 1	12.000	5.46	18.54	4.72	5	.005
Visual WM (Odd one out) Year 2	18.000	7.03	28.97	4.22	5	.008

children in both year 1 and 2 of the study. It is also important to note that the pattern of strengths and weaknesses in verbal STM and visual WM is the same regardless of the children's chronological age (e.g. 8;5–14;11 years). The standard scores for the verbal STM subtests and the visual WM subtest (i.e. odd-one out) are also presented in Table 3. The standard score of 100 is considered to be equivalent to the 50th percentile for the normative sample. As a group, the children with HI received higher scores than the age matched normative sample of hearing children on the visual WM task. That is to say that as a group their mean standard score in Year 1 was 112 (78th percentile) and in Year 2 was 118 (89th percentile). The current study group's standard scores ranged from 106 to 121. These scores are equivalent to the 66th to the 92nd percentile.

Discussion

The current research study focused upon the population of children with HI whose spoken language outcomes are extremely poor, despite long term use of their hearings aids or cochlear implant. All six participants in this study are significantly better at repeating lists of non-words than real words. The ability of the children with HI in this study to correctly repeat non-words better than their hearing peers, has not been observed in relation to the imitation of multisyllabic nonsense words [15,20,29,30]. The present study's results highlight that there may be difficulties for these children in retrieving words and/or accessing their lexicon, as they found repeating real words more difficult than non-words. This suggests that children with HI in this study may have inadequate representations of phonological information in their STM, which may make storage and retrieval processes less efficient and/or more difficult.

The findings from the present study complement those of Diller (2010) who also assessed the functioning of the phonological loop in his study of 24 CI users under the age of six. His findings suggest that the major difference is not the quantity of information processed by the CI children, but the quality of the processed information itself. However, the results from the current research study differed from that of Wass et al. [35] who found that CI children performed better when processing real words than non-words. They reported that the CI children in their study demonstrated poor phonological processing in relation to non-word repetition (NWR). It is important to note that the NWR task in their research utilized a test where the non-words increase in syllable length, which is different from the current study, which used single syllable CVC non-words.

With regards to visual working memory, the current findings support those of Wass et al. [35] and Lina-Granade et al. [20] who found that their CI users demonstrated visual memory abilities similar to that of their typically hearing peers. Interestingly, the participants in the present study perform significantly better than the normative sample of hearing peers on the visual WM task from the AWMA. The results from the visual WM subtest address the question as to whether there are generalised memory deficits in this population of children with HI and significant language delays. Their memory deficits appear to be located specifically in the verbal domain. The visual WM findings also address whether there are difficulties with the functioning of the central executive, as it is not a domain specific system, but a co-ordinator of information for both subsystems. As the children's visual WM abilities are well within normal limits in comparison to the normative sample, it suggests that there are no deficits within the central executive [22].

In summary, all six children with HI exhibited the same pattern of strengths and weaknesses in their verbal STM and visual WM over a two year period, despite their very different chronological ages. The results in verbal STM highlight that all participants found it more difficult to recall words than non-words, but were well within the average range or better on the visual WM task (e.g. odd one out). These findings have clinical and educational implications, which may have a positive impact upon language development and management of children with HI (see below).

Clinical and educational implications

It is apparent from the current research findings that these six children demonstrate weak verbal STM abilities and reduced efficiency for word retrieval. The children's strengths in visual memory abilities should be utilized in therapeutic and educational contexts. Therapists and teachers could create networks of semantically linked vocabulary using pictures of target vocabulary and linking them to previously targeted words. The use of pictures and structured input would enhance their word learning, thus providing the extra support that might allow the children to reallocate their resources, instead of struggling to maintain verbal

Table 6
Standard scores for all participants by memory assessment and year.

Child	Word recall Year 1	Non-word Year 1	Word recall Year 2	Non-word Year 2	Vis WM Year 1	Vis WM Year 2
A	81.00	104.00	78.00	124.00	107.00	103.00
B	75.00	97.00	75.00	97.00	122.00	121.00
C	90.00	117.00	98.00	118.00	113.00	112.00
D	78.00	101.00	78.00	95.00	108.00	126.00
E	101.00	123.00	85.00	93.00	106.00	114.00
F	65.00	118.00	90.00	134.00	116.00	132.00

Standard score <85 is at least one standard deviation below the mean.

information in their short-term memory. The use of additional visual information, when learning new vocabulary, may also help to create richer semantic and lexical representations, thus increasing their efficiency in storing and retrieving lexical items.

Interestingly, all six HI children in the current study, displayed poor vocabulary development as pre-schoolers, in that they struggled to retain and combine keywords, despite intensive input in clinical; educational and home environments. This pattern of word learning difficulty is supported by the research of Moeller [40] who reported that normally hearing and children with HI; aged between 10 and 30 months; exhibited four different profiles of word learning. She concluded that some children with HI follow a different developmental trajectory and that this delayed pattern continued over time. This slow pattern of word learning parallels that of the six children in the current study. It may be hypothesized; and is supported by the first author's clinical experience; that early difficulties with word learning; highlighted by Moeller; [40] have long term effects on language learning. That is to say; that these weaknesses may be observable in children with HI who find repeating "real" words more difficult than nonsense words; as well as exhibiting word finding difficulties. The hypothesis here is that the difficulties for some children with HI may be also due to a weakness in their ability to store new lexical items; which interacts with the additional difficulties of limited vocabulary and semantic knowledge. If these assumptions are supported other interventions beyond working memory training merit consideration.

Limitations of this research

The present research findings are limited by small participant numbers, and therefore cannot be generalized to all children with HI and language learning difficulties. However, the results from the current study parallel some of the findings from that of other researchers investigating verbal short-term memory and visual working memory in HI children. The methodology and results from the current study are original, as it is the only research to date that has been conducted with children with HI using subtests from the WMTB-C [28] and the AWMA [37]. Furthermore, the current research is one of few studies that target the sub-group of children with HI and additional language learning difficulties. These results would benefit from further investigation with children with HI, both with and without language impairment.

Non-word repetition task and new assessment tools

The results of this study also emphasize the need for specific memory assessments that are sensitive to the changes and developments in children with HI memory abilities. Non-word repetition (NWR) tasks are often administered via a CD, which may affect the children with HI ability to perceive target words. The traditional NWR task (of nonsense words that increase in syllable length) may only highlight that the task itself is difficult for children with HI, due to their perceptual difficulties. The unique difference, with the non-word recall task on the WMTB-C [28], is that it addresses the possible confounding variable of perceptual difficulties that may occur in the paediatric HI population. The ability of children with HI to perceive the subtle differences in multisyllabic words, without a semantic or syntactic context, is difficult and may adversely affect their scores. The use of a different NWR task, in conjunction with other measures of phonological short-term memory and verbal working memory, may highlight strengths and weaknesses that may be otherwise overlooked. The WMTB-C, addresses these issues, as it contains four subtests that evaluate the functioning of the phonological loop. The WMTB-C is also standardized on older children, thus increasing its validity and reliability when investigating longitudinal outcomes and changes in this population of children with HI.

Summary

In summary, the current research study targeted the population of children with HI who displayed additional language learning difficulties. The research found that all participants were significantly better at recalling non-words than real words, whilst also exhibiting strengths in visual working memory in comparison to the normative sample. The results suggest that these children with HI and language learning difficulties may have inadequate representations in their verbal STM, as well as difficulties in retrieving words from their lexicon. It is proposed that the strengths in their visual working memory need to be utilized in therapeutic and educational settings, as a way in which to support their word learning. Interestingly, all six participants in this study display the same pattern of strengths and weaknesses in verbal short-term memory and visual working memory despite their very different chronological ages, and the pattern is maintained throughout primary and secondary school. The participants' initial difficulties with word learning in combination with the poor ability to recall words may be indicators of children with HI who are at risk of language learning difficulties. Further research into the sub-group of children with HI and additional language learning difficulties, may provide researchers with much needed information that may allow for the development of target specific interventions that address their difficulties in the storage and retrieval of words. If these "tailor-made" interventions are implemented with children with HI at a young age, perhaps it may alter these children's developmental trajectories or even remediate their difficulties.

Conflict of interest

Non declared.

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Appendix 20 Conference Presentation

European Symposium on Paediatric Cochlear Implants, Athens, Greece, May 2011

HEARING-IMPAIRED CHILDREN WITH LANGUAGE LEARNING DIFFICULTIES: THEIR STRENGTHS & WEAKNESSES WITH PHONOLOGICAL AND VISUAL WORKING MEMORY

Suzi Willis, M.A., CCC-SLP[1], Juliet Goldbart PhD[1], Jois Stansfield EdD[1]

1. Manchester Metropolitan University, Manchester, U.K.

Aim: To compare phonological and visual working memory abilities of six congenitally hearing-impaired (HI) children with a normative sample of hearing children, using standardized assessments.

Method: Six children with HI aged 8-14 years were assessed using subtests from the Working Memory Test Battery and Automated Working Memory Assessment. All had cognitive abilities within normal limits and spoken language as the primary mode of communication. Children were fitted with hearing aids by 2 years and transitioned to cochlear implants where appropriate by 3½ years. Despite this, all showed significant delays in language.

Results: Visual Working Memory and Phonological Memory abilities for nonsense words for the HI children were significantly higher than those of the age-matched normative sample. The HI children were significantly poorer at recalling real words than their hearing peers.

Conclusion: The language learning difficulties of these 6 children may relate to their ability to store and retrieve auditory information.